OLD DOMINION UNIVERSITY

[1]Department of Biological Sciences
Old Dominion University, Norfolk, Virginia 23529

[2]Department of Chemistry and Biochemistry
Old Dominion University, Norfolk, Virginia 23529

[3] Chesapeake Bay Program Office
Virginia Department of Environmental Quality,
Richmond, Virginia 23230

STATUS AND TRENDS IN WATER QUALITY AND LIVING RESOURCES IN THE VIRGINIA CHESAPEAKE BAY: YORK RIVER (1985-2002)

Prepared by

Principal Investigators:

Dr. Daniel M. Dauer[1]
Dr. Harold G. Marshall[1]
Dr. John R. Donat[2]
Mr. Michael F. Lane[1]
Ms. Suzanne Doughten[1]
Mr. Frederick Hoffman[3]

Submitted to:

Chesapeake Bay Program Office
Virginia Department of Environmental Quality
629 East Main Street
Richmond, Virginia 23230

December 2003

OLD DOMINION UNIVERSITY

[1]Department of Biological Sciences
Old Dominion University, Norfolk, Virginia 23529

[2]Department of Chemistry and Biochemistry
Old Dominion University, Norfolk, Virginia 23529

[3] Chesapeake Bay Program Office
Virginia Department of Environmental Quality,
Richmond, Virginia 23230

STATUS AND TRENDS IN WATER QUALITY AND LIVING RESOURCES IN THE VIRGINIA CHESAPEAKE BAY: YORK RIVER (1985-2002)

Prepared by

Principal Investigators:

Dr. Daniel M. Dauer[1]
Dr. Harold G. Marshall[1]
Dr. John R. Donat[2]
Mr. Michael F. Lane[1]
Ms. Suzanne Doughten[1]
Mr. Frederick Hoffman[3]

Submitted to:

Chesapeake Bay Program Office
Virginia Department of Environmental Quality
629 East Main Street
Richmond, Virginia 23230

December 2003

Preface

This material in this report was produced for the Virginia Department of Environmental Quality in order to summarize patterns of status and trends in water quality, phytoplankton, primary productivity, zooplankton and benthos collected as part of the Virginia Chesapeake Bay Program. There are three reports, referred to as basin summaries, one each for the James River, the York River and the Rappahannock River. These basin summaries are intended to be electronic reports that will be periodically updated and they were intended for an audience already knowledgeable of the history and rationale of the program; design of the program; field and laboratory methods; specialized parameters, e.g. the Benthic Index of Biotic Integrity; status and trends analytical methods, etc.

In order to create a record of past patterns in status and trends and to make these data more widely available, a printed version of each basin summary was produced. To make the information more interpretable we have added an introduction and a methods section. However, this report is a data report and is not a comprehensive, interpretive report. Therefore, there is no discussion section to this report.

All three basin summaries and appendices are available at the Old Dominion University Chesapeake Bay Program website <www.chesapeakebay.odu.edu> under "Reports." The James River Report includes the Elizabeth River, the Chickahominy River and the Appomattox River. The York River Report includes the tidal Pamunkey River and Mattaponi River. The Rappahannock River Report includes the Corrotoman River. Also available at this website are appendices that include (1) tables of status for all parameters measured at all stations sampled by each program, (2) tables of all parameters and metrics for which there was a significant trend, and (3) scatter plots of all parameters over time. There are five appendices: water quality, phytoplankton, primary productivity, zooplankton and benthos.

Table of Contents

Summary v

Chapter 1. Introduction 1

Chapter 2. Monitoring Program Descriptions 2

I. Water Quality 2
A. Sampling Locations and Procedures 2
B. Laboratory sample processing 2

II. Phytoplankton 3
A. Sampling Locations and Procedures 3
B. Laboratory Sample Processing 3

III. Microzooplankton 4
A. Sampling Locations and Procedures 4
B. Laboratory Sample Processing 4

IV. Benthos 4
A. Fixed Location Sampling 4
B. Probability-based Sampling 5
C. Laboratory Sample Processing 5

V. Statistical Analyses 6
A. Status Assessments 6
B. Long-term Trend Analyses 8

Chapter 3. York River Basin 15

I. Executive Summary 15
A. Summary of Basin Characteristics 15
B. Summary of Status and Long Term Trends 15
C. Summary of Major Issues in the Basin 17

II. Management Recommendations 17

III. Overview of Basin Characteristics 18

IV. Overview of Monitoring Results 20

V. Detailed Overview of Status and Trends 21
A. Fall-Line 21
B. Mobjack Bay (MOBPH) 21
C. Polyhaline York River (YRKPH- Lower York) 23

D. **Mesohaline York River (YRKMH - Middle York)** 24
E. **Oligohaline Pamunkey River (PMKOH - Lower Pamunkey)** 25
F. **Tidal Freshwater Pamunkey River (PMKTF - Upper Pamunkey)** 26
G. **Oligohaline Mattaponi River (MPNOH - Lower Mattaponi)** 27
H. **Tidal Freshwater Mattaponi River (MPNTF - Upper Mattaponi)** 28

Literature Cited 66

Glossary of Important Terms 70

List of Appendices (on attached CD-ROM)

Appendix A.	**Relative status of water quality in the Virginia tributary and mainstem stations for the period of 2000 to 2002.**
Appendix B.	**Long-term trends in water quality for the Virginia tributary and mainstem stations for the period of 1985 through 2002.**
Appendix C.	**Scatterplots of water quality parameters.**
Appendix D.	**Status of phytoplankton bioindicators at the Virginia tributary and mainstem stations for the period of 2000 to 2002.**
Appendix E.	**Long term trends in phytoplankton bioindicators at the Virginia tributary and mainstem stations from the start of monitoring through 2002.**
Appendix F.	**Scatterplots of phytoplankton bioindicators.**
Appendix G.	**Status of primary productivity at the Virginia tributary and mainstem stations for the period of 2000 to 2002.**
Appendix H.	**Long term trends in primary productivity at the Virginia tributary and mainstem stations for the period of 1989 through 2002.**
Appendix I.	**Scatterplots of primary productivity.**
Appendix J.	**Status of microzooplankton bioindicators at the Virginia tributary and mainstem stations for the period of 2000 through 2002.**
Appendix K.	**Long term trends in microzooplankton bioindicators at the Virginia tributary and mainstem stations for the period of 1993 through 2002.**
Appendix L.	**Scatterplots of microzooplankton bioindicators.**
Appendix M.	**Status in benthic community condition based on the B-IBI at the Virginia tributary and mainstem stations for the period of 2000 through 2002.**
Appendix N.	**Long term trends in benthic bioindicators at the Virginia tributary and mainstem stations for the period of 1985 through 2002.**
Appendix S.	**Scatterplots of the B-IBI.**
Appendix T.	**Scatterplots of the B-IBI components metrics.**

Summary

The Virginia Chesapeake Bay and its tidal tributaries continue to show some environmental trends indicating progress toward restoration of a more balanced and healthy ecosystem. However, the Bay system remains degraded and some areas and indicators show continuing degradation. Progress in reducing nutrient inputs has made demonstrable improvements and we expect that continued progress toward nutrient reduction goals, along with appropriate fisheries management and chemical contaminant controls, will result in additional improvements to the Bay. An overall summary of findings for the major VA Bay tributaries (i.e. James, York, and Rappahannock Rivers) is bulleted below while the remainder of this report focuses on the detailed results for the York River. Overall patterns of nutrient and sediment loads are summarized in Table 1.

- Nonpoint source loads (estimates of controllable and uncontrollable) of phosphorus, nitrogen, and sediment as calculated by the Bay Program Watershed Model, decreased by 7%, 9%, and 11%, respectively, compared to the 1985 baseline loads.

- Point source nutrient loads were reduced by 57% for phosphorus and 20% for nitrogen, compared to the 1985 baseline loads. This decrease in discharge may be partly due to ongoing drought conditions in Virginia.

- Combined nutrient loads were reduced by 26% for phosphorus and 13% for nitrogen, compared to the 1985 baseline loads.

- For phosphorus, there were improving trends above the fall-line at the river input stations of the James River, Appomattox River, Mattaponi River, and Rappahannock River with a degrading trend in the Pamunkey River. The improving trends are indicative of both point and nonpoint source nutrient reductions over the last 18 years. Both improving trends many degrading trends in phosphorus were detected were detected in the Virginia tributaries. Overall, there were 10 areas with improving trends and 11 areas with degrading trends in this parameter within the Virginia tributaries. Nearly half of those areas with improving trends in phosphorus were located in the Elizabeth River.

- For nitrogen, there were improving trends above the fall-line at the river input stations of the James River, Appomattox River, Mattaponi River and Rappahannock River and a degrading trend in the Pamunkey River. Overall, there were nine areas showing improving trends but only two areas showing degrading trends for nitrogen. Nitrogen levels showed improving trends in nearly segments all of the Elizabeth River.

- Chlorophyll *a* levels are moderately high throughout much of the tidal waters. Degrading trends were widespread geographically and indicative of detrimentally high nutrient levels. Overall, six areas showed degrading trends in chlorophyll *a* and four showed an improving trend. Every tributary had at least one degrading trend in chlorophyll *a* except the Elizabeth River.

- Water clarity, a very important environmental parameter, was generally fair or poor throughout the tributaries and degrading trends were detected five areas in the tributaries. This is probably related to high and scattered increasing levels of suspended solids. These degrading conditions in the Virginia Chesapeake Bay may result in degradation of zooplankton populations and are a major impediment to restoration of submerged aquatic vegetation (SAV). Overall, there were five areas showing improving trends and six areas showing degrading trends in water clarity.

- Levels of dissolved oxygen are improving in geographically widespread areas of the tidal rivers. Overall, there were 11 areas showing improving trends and no areas showing degrading trends for dissolved oxygen conditions. Dissolved oxygen conditions were good in most of the segments in the Virginia tributaries.

- The Virginia tributaries continue to contain favorable diatom populations that are generally dominant among the other flora in their abundance and biomass. However, there are increasing population trends among the cyanobacteria and dinoflagellates that are degrading and represent a less favorable phytoplankton population for these rivers. If these trends continue they would directly impact the trophic status and balance within the plankton community. Any increased development of dinoflagellate blooms within these rivers is another concern.

- Degrading trends and poor status of microzooplankton communities were observed in all of Virginia tributaries except the Elizabeth River. Most of the degrading trends and poor status occurred in the lower portions of each of the three major tributaries. Improving trends in the microzooplankton were observed in the Upper and Middle James River. Degrading trends in the microzooplankton may be related to degrading trends in nutrients and water clarity indicators and/or the decreasing trends in salinity observed in these regions.

- Benthic community patterns differed greatly between the rivers. In the James River there strong improving trends upstream and continued good status down stream. In the Elizabeth River there was a strong improving trend although the status of the benthic communities remains poor. In the York River and the Rappahannock River there are degrading trends in the middle reaches.

Table 1. Nutrient and Sediment Loads for Virginia (2001). Modified from data provided by the Virginia Department of Environmental Quality. Phosphorous and nitrogen loads are in kg/year and sediment loads are metric tons/year. Percent change compares 2001 data to 1985 data. Nonpoint source loads are results based on the Year 2000 Progress Run of Phase 4.3 of the Chesapeake Bay Watershed Model and calculated reductions for calendar year 2001 Best Management Practices (BMPs) as monitored by the Department of Conservation and Recreation. Values with a "*" were updated with the latest available point source data.

River Basin	2001 Phosphorus Load	Percent Change in Phosphorus	2001 Nitrogen Load	Percent Change in Nitrogen	2001 Sediment Load	Percent Change in Sediment
A. Nonpoint Loads						
Potomac	749,527	-10.5%	6,305,959	-10.1%	650,655	-13.4%
Rappahannock	396,532	-19.5%	3,372,686	-19.9%	297,812	-21.4%
York	297,250	-13.4%	3,089,427	-13.3%	126,172	-12.2%
James	2,037,523	- 0.8%	10,316,677	- 2.7%	1,085,925	- 5.4%
Coastal	88,295	-14.2%	943,327	- 5.0%	17,581	-17.2%
Totals	3,569,127	- 7%	24,028,077	- 9%	2,178,145	-11%
B. Point Source Loads. In parentheses is the number of significant point source discharges.						
Potomac (40)	251,218	-28%	5,336,045	+8%		
Rappahannock (14)	21,813*	-74%	246,721*	+11%		
York (9)	84,618*	-59%	502,801*	-20%		
James (30)	607,670*	-62%	6,974,083*	-44%		
Coastal (8)	66,482	-56%	826,527	+40%		
Totals	1,031,801	-57%	13,886,177	-20%		
C. Total Loads. All river basins combined.						
Nonpoint Source	3,569,127	-7%	24,028,077	-9%	2,178,145	-10.8%
Point Source	1,031,801	-57%	13,886,177	-20%		
Combined Loads	4,600,928	-26%	37,914,254	-13%	2,178,145	-10.8%

Chapter 1. Introduction

A marked decline in the water quality of the Chesapeake Bay has occurred over the past several decades. The disappearance of submerged aquatic vegetation in certain regions of the Bay, declines in the abundance of some commercially and recreationally important species, increases in the incidence of low dissolved oxygen events, changes in the Bay's food web, and other ecological problems have been related to the deteriorating water quality. The results of concentrated research efforts in the late 1970s and early 1980s stimulated the establishment of Federal and state directives to better manage the Chesapeake Bay watershed. By way of the Chesapeake Bay Agreements of 1983, the State of Maryland, the Commonwealths of Virginia and Pennsylvania, and the District of Columbia, agreed to share the responsibility for improving environmental conditions in the Chesapeake Bay. As part of this agreement, a long-term monitoring program in the Chesapeake Bay was established in order to: 1) track long-term trends in water quality and living resource conditions over time, 2) assess current water quality and living resource conditions, and 3) establish linkages between water quality and living resources communities. By tracking long-term trends in water quality and living resources, managers may be able to determine if changes in water quality and living resource conditions have occurred over time and if those changes are a reflection of management actions. Assessments of current status may allow managers to identify regions of concern that could benefit from the implementation of pollution abatement or management strategies. By identifying linkages between water quality and living resources it may be possible for managers to determine the impact of water quality management practices on living resource communities.

Water quality and living resource monitoring in the Virginia Mainstem and tributaries began in 1985 and has continued for 18 years. Detailed assessments of the status and long-term trends in water quality and living resources in Chesapeake Bay and its tributaries have been previously conducted (Alden et al., 1991,1992; Carpenter and Lane, 1998; Dauer, 1997; Dauer et al., 1998a, 1998b, 2002, 2003a,b,c; Lane et al.,1998; Marshall, 1994,1996; Marshall and Burchardt, 1998; Marshall et al., 1998). An attempt was made to determine if there was concordance in current conditions of, and long-term changes, in water quality and living resources. The purpose of this project was to reassess the results of these studies by re-conducting the analyses after adding data collected during 2002. This report describes the status of water quality and living resource conditions for the Virginia Mainstem and tributaries, summarizes major long-term trends in water quality and measures of living resource community health.

Chapter 2. Monitoring Program Descriptions

I. Water Quality

A. Sampling Locations and Procedures

As part of the U. S. Geological Survey's River Input Program, water quality data have been collected at five stations near the fall line and three stations above the fall line in Virginia. Samples were taken at base-flow twice a month and during high flows whenever possible between 1988 and 2002. Water quality data have also been collected by the Virginia Department of Environmental Quality (DEQ) at three additional stations upstream of these River Input sites (Figure 2-1). These stations had a minimum of three consecutive years of samples taken between 1985 and 1996 with sampling occurring on at least a monthly basis.

Water quality conditions were regularly monitored at 28 sites in the Bay Mainstem beginning in July, 1985. From 1985 until 1995 eight stations were sampled by Old Dominion University (ODU) and 20 stations were sampled by the Virginia Institute of Marine Science (VIMS). From 1995 through the present, Mainstem water quality monitoring was conducted by ODU. Tributary water quality monitoring was conducted by the Virginia DEQ at 27 sites in the James, York (including the Mattaponi and Pamunkey) and Rappahannock rivers (Figure 2). In addition, six permanent water quality monitoring sites were established in the Elizabeth River/Hampton Roads Harbor by ODU in February, 1989 (Figure 2-2). In August 1990, station LAF1 was dropped from the Elizabeth River Long Term Monitoring (ERLTM) Program.

The temporal sampling scheme for the water quality monitoring program changed several times over the 18 year period (varying from 20 to 12 sampling events per year) as a result of changes in the monitoring program budget. In general, Mainstem sampling cruises were conducted semi-monthly from March through October and monthly from November through February until 1996. Starting in 1996 Mainstem sampling cruises were conducted semi-monthly for July and August and monthly the rest of the year. Tributary sampling by the Virginia Department of Environmental Quality was generally conducted 20 times per year. The Elizabeth River stations were sampled monthly. Field sampling procedures used for ODU and VIMS water quality collections are described in detail by Alden et al. (1992a). Field sampling procedures for DEQ water quality collections are described in detail in DEQ's Quality Assurance Project Plan for the Chesapeake Bay Program (Donat and Doughten, 2002).

B. Laboratory sample processing

Descriptions of laboratory sample processing and standard operating procedures for all water quality parameters are found in the Chesapeake Bay Program Quality Assurance Project Plans (QAPjPs) prepared by each of the participating laboratories (Donat and Doughten, 2002). Copies of the QAPjPs can be obtained by contacting EPA's Chesapeake Bay Program Quality Assurance Officer.

II. Phytoplankton

A. Sampling Locations and Procedures

Seven stations were established in Chesapeake Bay in July 1985. These were CB6.1, CB6.4, CB7.3E, CB7.4, LE5.5, WE4.2, and LE3.6 (Figure 2-3). From July, 1985 through September, 1990, phytoplankton collections were taken from these stations twice a month from March through October, and monthly November through February. From October, 1990, monthly samples were taken at all Bay stations. Monthly sample collections and analysis in the James (TF5.5, RET5.2), York (RET4.1, RET4.3), and Rappahannock (TF3.3, RET3.1) rivers began in March, 1986. In March, 1987, station RET4.1 in the Pamunkey River was replaced by station TF4.2, and in February, 1989, monthly collections began at two stations (SBE2, SBE5) in the Elizabeth River. Picoplankton analysis was included at several trial stations in January, 1989, and was expanded to include all stations in July, 1989. Primary production analysis was added to all Bay and tributary stations in July 1989.

At each station, two vertical sets of three liter water samples were taken at five equidistant depths above the pycnocline and placed in two separate carboys. The process was repeated at five depths below the pycnocline. The water in each carboy was carefully mixed and replicate 500 ml sub-samples were removed from each carboy, and fixed with Lugol's solution. A second set of 125 ml sub-samples were also taken above and below the pycnocline, preserved with glutaraldehyde and placed in a cooler. These samples were taken to determine the concentrations of the autotrophic picoplankton population. An additional replicate set was also taken from the same carboy set taken above the pycnocline for primary productivity measurements.

B. Laboratory Sample Processing

Samples for phytoplankton analyses were passed through a series of settling and siphoning steps to produce a concentrate (or fraction of the concentrate) that was examined using a modified Utermöhl method with an inverted plankton microscope (Marshall and Alden, 1990). The analysis procedure attained an estimated precision of 85% (Venrick, 1978). The autotrophic picoplankton were processed through a protocol that included their collection on a 0.2 Φ nucleopore filter, with subsequent analysis using an epifluorescent microscope, under oil at 1000x magnification, with "green" and “blue” filter sets (Marshall, 1995). Supplemental analysis with a scanning electron microscope was used in several of the species identifications. Methodology for the productivity measurements is given in Marshall and Nesius (1996). Appropriate quality assurance/quality control practices in sample collection, analysis, and data entry were employed throughout this period.

III. Microzooplankton

A. Sampling Locations and Procedures

Microzooplankton communities were monitored monthly at seven sites in the Mainstem and six sites in the Virginia tributaries beginning in January, 1993 (Figure 2-3). Whole water samples were collected at all stations. Before sampling, 10 ml of modified Lugol's solution was placed into two liter (L) bottles designated for each station. The water was sampled through the use of a battery powered pump attached to a hose. Two composite water samples, each totaling 15 L, were taken from five equidistant depths above the pycnocline and collected in two carboys. Each carboy was thoroughly mixed and 1 L taken from each (Samples A and B for each station).

B. Laboratory Sample Processing

The whole water samples taken for microzooplankton (<200Φ) analysis were processed through a screen, plus a series of settling and siphoning procedures (Park and Marshall, 1993). These steps removed the larger zooplankters and debris to provide 3 sub-sets based on size to be analyzed. This method insured the collection and analysis of the small non-loricated ciliates to be included in the count.

IV. Benthos

A. Fixed Location Sampling

Sixteen stations in the lower Chesapeake Bay were sampled quarterly (March, June, September, December) from March 1985 through December 1995 as part of the Benthic Biological Monitoring Program of the Chesapeake Bay Program. Beginning in 1996 sampling at the fixed stations occurred only in June and September and a stratified random sampling element was added to the program. Power and robustness analyses indicated that sampling during June and September would be sufficient for detecting long-term trends at the fixed locations while at the same time, allow funding resources to be reallocated to the probability-based random sampling regime (Alden et al., 1997). Stations were located within the mainstem of the bay and the major tributaries - the James, York and Rappahannock rivers (Figure 2-3). In the tributaries, stations were located within the tidal freshwater zone (TF5.5, TF4.2, TF3.3), turbidity maximum (transitional) zone (RET5.2, RET4.3, RET3.1), lower estuarine mesohaline muds (LE5.2, LE4.1, LE3.2) and lower estuarine polyhaline silty-sands (LE5.4, LE4.3). The tidal freshwater station within the York River estuary was located in the Pamunkey River. In the Mainstem of the Bay three stations were located off the mouths of the major tributaries (CB8.1, CB6.4, CB6.1) and two stations in the deeper channels near the bay mouth (CB7.3E) and above the Rappahannock River near the Virginia-Maryland border (CB5.4).

In 1989, five additional stations were added to the program: two stations in the Southern Branch of the Elizabeth River (SBE2, SBE5) in regions exposed to contaminated sediments, a station in the transitional region of the James River (LE5.1), a station in the lower York River exposed to low dissolved oxygen events (LE4.3B), and a station in the lower Rappahannock River exposed to low dissolved oxygen events (LE3.4).

For the fixed-point stations three replicate box core samples were collected for benthic community analysis. Each replicate had a surface area of 184 cm^2, a minimum depth of penetration to 25 cm within the sediment, was sieved on a 0.5 mm screen, relaxed in dilute isopropyl alcohol and preserved with a buffered formalin-rose bengal solution.

At each station on each collection date a 50g subsample of the surface sediment was taken for sediment analysis. Salinity and temperature were measured using a Beckman RS5-3 conductive salinometer and bottom dissolved oxygen was measured using a YSI Model 57 oxygen meter. For the original 16 stations see Dauer et al. (1992) for a summary of the pattern of bottom oxygen values, Dauer et al. (1993) for a summary of the distribution of contaminants in the sediments and Dauer (1993) for a summary of salinity, water depth, and sedimentary parameters.

B. Probability-based Sampling

In 1996 a probability-based sampling program was added to estimate the area of the Virginia Chesapeake Bay and its tributaries that met the Benthic Restoration Goals as indicated by the B-IBI (Ranasinghe et al., 1994; Weisberg et al., 1997; Alden et al., 2002). Four strata were defined and each stratum was sampled by 25 randomly allocated sites. The four strata were: 1) the James River; 2) the York River (including the Pamunkey and Mattaponi rivers); 3) the Rappahannock River; and 4) the Mainstem of the Chesapeake Bay. Each year a new set of 25 random sites was selected for each stratum.

Probability-based sampling within strata supplements data collected at fixed-point stations. Sampling design and methods for probability-based sampling are based upon those developed by EPA's Environmental Monitoring and Assessment Program (EMAP, Weisberg et al., 1993) and allow unbiased comparisons of conditions between strata (e.g., tributaries) of the Chesapeake Bay within the same collection year and within tributaries for between different years. The consistency of sampling design and methodologies for probability-based sampling between the Virginia and Maryland benthic monitoring programs allows bay-wide characterizations of the condition of the benthos for the Chesapeake Bay (Dauer 1999; Dauer and Rodi 1998a, 1998b, 1999, 2001, 2002).

Within each probability-based stratum, 25 random locations were sampled using a 0.04 m^2 Young grab. At each station one grab sample was taken for macrobenthic community analysis and a second grab sample for sediment particle size analysis and the determination of total volatile solids. All sampling processing for probability-based sampling stations were identical to those for the fixed stations. Physico-chemical measurements were also made at the random locations.

C. Laboratory Sample Processing

In the laboratory, each replicate was sorted and all the individuals identified to the lowest possible taxon and enumerated. Biomass was estimated for each taxon as ash-free dry weight (AFDW) by drying to constant weight at 60 ^{o}C and ashing at 550 ^{o}C for four hours. Biomass was expressed as the difference between the dry and ashed weight.

The sand fraction of each sediment sample was dry sieved and the silt-clay fraction was quantified by a pipette analysis using the techniques of Folk (1974). Total volatile solids for each sediment sample was determined as the AFDW weight of the sediment divided by the dry weight of the sediment, expressed as a percentage.

V. Statistical Analyses

In order to ensure that long-term trends in water quality and living resource data are correctly interpreted, a unified approach for conducting the statistical analyses and interpreting their results was developed. Statistical analytical procedures used in this study were based on guidelines developed by the CBP Monitoring Subcommittee's Tidal Monitoring and Assessment Workgroup. For both status and trend analyses, the stations were grouped into segments based on the segmentation scheme developed by the Data Analysis Workgroup (Figure 2-2). Status and trend analyses were conducted for different time periods or “seasons” as defined for each monitoring component in Table 2-1.

A. Status Assessments

For the tidal water quality stations, status analyses were conducted using surface and bottom water quality measurements for six parameters: total nitrogen, dissolved inorganic nitrogen, total phosphorus, dissolved inorganic phosphorus, chlorophyll *a*, and total suspended solids. Status analyses were also performed on secchi depth and bottom dissolved oxygen. All analyses were conducted using water quality data collected from all of the Chesapeake Bay Mainstem and tributary collection stations from the January 2000 through December of 2002 except for bottom dissolved oxygen for which analyses were conducted using data collected only during the summer months of June through September.

The relative status of each station and segment was determined by comparison to a benchmark data set comprised of all data collected from 1985 to 1990 by both the Virginia and Maryland monitoring programs. Each station was rated as poor, fair, or good relative to the benchmark data. The ratings are obtained for data collected within each salinity zone with salinity zones being assigned using the Venice classification system (Symposium on the Classification of Brackish Waters, 1958). For each parameter in the benchmark data set, a transformation was chosen that yields a distribution that was symmetric and approximated by the logistic cumulative distribution function (CDF). In most cases, the logarithmic transformation was selected. A logistic CDF based on the mean and variance of each parameter of the benchmark data set was used to perform a probability integral transform on all data collected during the period of January, 2000 through December, 2002. This resulted in data in the interval (0,1) that follow a uniform distribution. The three year median of these transformed data was computed as an indicator of status for the period specified. The median of n observations taken from a uniform distribution follows a Beta distribution with parameters (m,m) where:

$$m = (n+1)/2$$

and n is the number of observations. The transformed three year medians were compared to the Beta density distribution and status was determined by the placement of the transformed medians along the distribution. If the median was in the upper third of the distribution (where upper is chosen as the end of the distribution that is ecologically desirable) then the status rating is good, while a median in the middle third was rated fair, and a median in the lower third was rated poor. In most cases, serial dependence of the raw data resulted in greater than expected variance in the Beta density of the medians. To adjust for this, the variance of the Beta density was increased by a function of the ratio of among station variance to within station variance.

Because sampling regimes between monitoring programs varied with respect to the number of collection events within a given month and the number of replicate samples collected at each station varied, a uniform calculation protocol was adopted for use by both states to insure that the calculations were not inadvertently biased by these discrepancies. First, replicate values were combined by calculating a median for each station date and layer combination. Median values for each station month and year combination were calculated to combine separate cruises per month. Finally, station specific or segment specific median scores were calculated that were compared to the benchmark scale.

Water quality data were also assessed to determine if the SAV habitat requirements were met for the following parameters: chlorophyll *a*, total suspended solids, secchi depth, dissolved inorganic nitrogen, and dissolved inorganic phosphorus. Three year medians for the SAV growing season were compared to the SAV habitat requirement values (see Table 2-2) using a Mann-Whitney U-test. If the median values were significantly higher than the habitat requirement for that parameter then the parameter was considered to have failed to met the SAV habitat requirements and if the values were significantly lower (higher for secchi depth) than the habitat requirement then the parameter was to considered to have met the SAV habitat requirement. If there was no significant difference between the habitat requirements or there were insufficient data to conduct the analysis, the parameter was considered borderline.

Status for phytoplankton, and microzooplankton involved the calculation of relative status using the same technique as described for water quality relative status assessments. For phytoplankton communities the following indicators were assessed: total phytoplankton community abundance, total phytoplankton community biomass, diatom abundance, dinoflagellate abundance, cyanobacteria abundance, picoplankton abundance, and primary productivity (carbon fixation). Benchmarks for picoplankton abundance were made using data collected only in Virginia since sampling protocols for the Maryland program did not include counts of epifluorescent picoplankton. Microzooplankton parameters assessed included copepod nauplii abundance and rotifer abundance.

Status of benthic communities at each station was characterized using the three-year mean value (2000 through 2002) of the B-IBI (Weisberg et al., 1997). The B-IBI indicates whether the macrobenthic community meets the restoration goals developed for benthic habitats of the Chesapeake Bay. An index value that exceeds or equals 3.0 indicates that the macrobenthic community meets or exceeds the restoration goals developed for that habitat type while a value below 3.0 indicates that the macrobenthic community does not meet the restoration goals. Status of the benthic community was classified into four levels based on the B-IBI. Values less than or equal to 2 were classified as severely degraded, values from 2.0 to 2.6 were classified as degraded, values greater than 2.6 but less than 3.0 were classified as marginal, and values of 3.0 or more were classified as meeting goals.

B. Long-term Trend Analyses

1. Non-tidal water quality

Trend analyses were conducted on data collected at nine stations at and above the fall-line in the Virginia tributaries. Concentrations of water-quality constituents are often correlated with streamflow. Removal of natural flow variability allows examination of changes in water quality resulting from human activities. Flow-adjusted concentration trends were determined with a non-parametric Kendall-Theil analysis. The trend slope was the overall median of the pairwise slopes of residuals from a log-linear-regression model incorporating flow and season terms. For data sets with greater than five percent censored data, a range in slope and magnitude was defined by twice computing the median slope - first, with censored data equal to zero and second, with censored data equal to the maximum detection limit. For data sets with greater than twenty percent censored data, no results were reported. A p-value of 0.05 or less was considered significant for this analysis.

When considering the health of living resources, it is necessary to examine trends in concentrations that may be both flow- and human-induced. These concentrations were weighted, but not adjusted, for flow. The flow-weighting resulted in a more representative monthly concentration than the one point per month typical of many observed data sets. The volume of flow occurring between these infrequent sample dates is likely to have a pronounced effect on average concentrations in the tidal estuaries and other mixed receiving areas. Therefore trends in flow-weighted concentrations may correlate better with trends in estuarine concentrations. The linear trend in flow-weighted concentration was estimated by regressing flow-weighted concentrations with time. In most cases, the data was log-transformed in order to meet the assumptions of normality, constant variance, and linearity. A p-value of 0.01 or less was considered significant for this analysis.

2. Tidal water quality

Trend analyses were conducted on the same suite of water quality parameters used for the status assessments and salinity and water temperature. Prior to the trend analyses, data were reduced to a single observation for each station month and layer combination by first calculating the median of all replicates for each layer by station and date and then calculating the median between all dates for a given station within each month. For all applicable water quality parameters, any values less then the highest detection limit were set to one half of the highest detection limit. For calculated parameters, each constituent parameter that was below the detection limit was set to one half of the detection limit and the parameter was then calculated.

Increasing trends in total nitrogen, dissolved inorganic nitrogen, total phosphorus, dissolved inorganic phosphorus, chlorophyll *a* and total suspended solids should indicate increased eutrophication and as a result positive slopes in these parameters indicate degrading conditions while negative slopes indicate improving water quality conditions. Increasing trends in secchi depth and bottom dissolved oxygen indicate increasing water clarity and reduced eutrophication, respectively and, as a result, indicate improving water quality conditions. Decreasing trends in these two parameters indicate degrading conditions.

In 1994, changes in analytical methods for estimating concentrations of total nitrogen, dissolved inorganic nitrogen, total phosphorus and dissolved inorganic phosphorus were implemented by the Department of Environmental Quality in order to improve the accuracy of concentration estimates. These changes resulted in step trends in these parameters. In order to compensate for the step trends, a "blocked" seasonal Kendall approach (Gilbert, 1987) was used to compare trends conducted between two separate time periods which in this case were the pre-method (1985 through 1993) and post-method change (1995 through 2002) time periods for these parameters. Note that 1994 was eliminated from the analyses because samples during this year were collected and processed by laboratory that was different than the DEQ. The "blocked" seasonal Kendall test was applied only to those segment/parameter combination for which a method change occurred. The statistical tests used for all other segment/parameter combinations were the seasonal Kendall test for monotonic trends and the Van Belle and Hughes tests for homogeneity of trends between stations, seasons, and station-season combinations (Gilbert, 1987).

A p value of 0.05 was chosen as the statistical test criterion for all water quality trend analyses. Recent studies on representative data sets from the Chesapeake Bay monitoring program have indicated that these tests are very powerful and robust, even when data violate most of the assumptions of parametric statistics (Alden et al., 1991; Alden et al., 1992b; Alden et al., 1994; Alden and Lane, 1996).

3. Living resources

Trend analyses for phytoplankton communities were conducted on the following phytoplankton community indices: the phytoplankton IBI, total phytoplankton abundance (excluding picoplankton); total phytoplankton biomass (excluding picoplankton); the Margalef species diversity index, and C^{14} productivity. In addition, trend analyses were conducted on abundance and biomass values for the following taxonomic groups: diatoms; dinoflagellates; cyanobacteria; cryptomonads; chlorophytes; bloom producing species; and toxic bloom producing species.

The Margalef species diversity index was calculated as follows:

$$D = \frac{S - 1}{\log_2 N}$$

where S is the number of taxa in the sample and N is the number of individuals (Margalef, 1958).

Trend analyses for microzooplankton communities were conducted by station using monthly medians of microzooplankton collected from the beginning of the monitoring program through December of 2002. Microzooplankton bioindicators used for the trend analyses included: total microzooplankton abundance, rotifer abundance, copepod nauplii abundance, oligotrich abundance, tintinnid abundance, sarcodinia abundance, and microzooplankton cladoceran abundance.

Trend analyses for benthic communities were conducted using the B-IBI (Ranasinghe et al., 1994; Weisberg et al., 1997) and on selected metrics of the B-IBI. Benthic restoration goals were developed for benthic habitats of the Chesapeake Bay based upon reference sites that were minimally impacted by low dissolved oxygen events and sediment contaminants. Goals were developed based upon data from an index period of July 15 through September 30. Therefore trends in the value of the B-IBI were based upon September cruise values for the 17 year period of 1985-2002. Selected benthic metrics were species diversity (H'), community abundance, community biomass, pollution-indicative species abundance, pollution-indicative species biomass, pollution-sensitive species abundance, and pollution-sensitive species biomass. See Weisberg et al. (1997) for a list of pollution-indicative and pollution-sensitive taxa.

The statistical tests used for the living resources bioinidcators were the seasonal Kendall test for monotonic trends and the Van Belle and Hughes tests for homogeneity of trends between seasons (Gilbert, 1987). Statistical test criterion for the phytoplankton and microzooplankton was a p value of 0.05 while the criterion for the benthic bioindicators was a p value of 0.10.

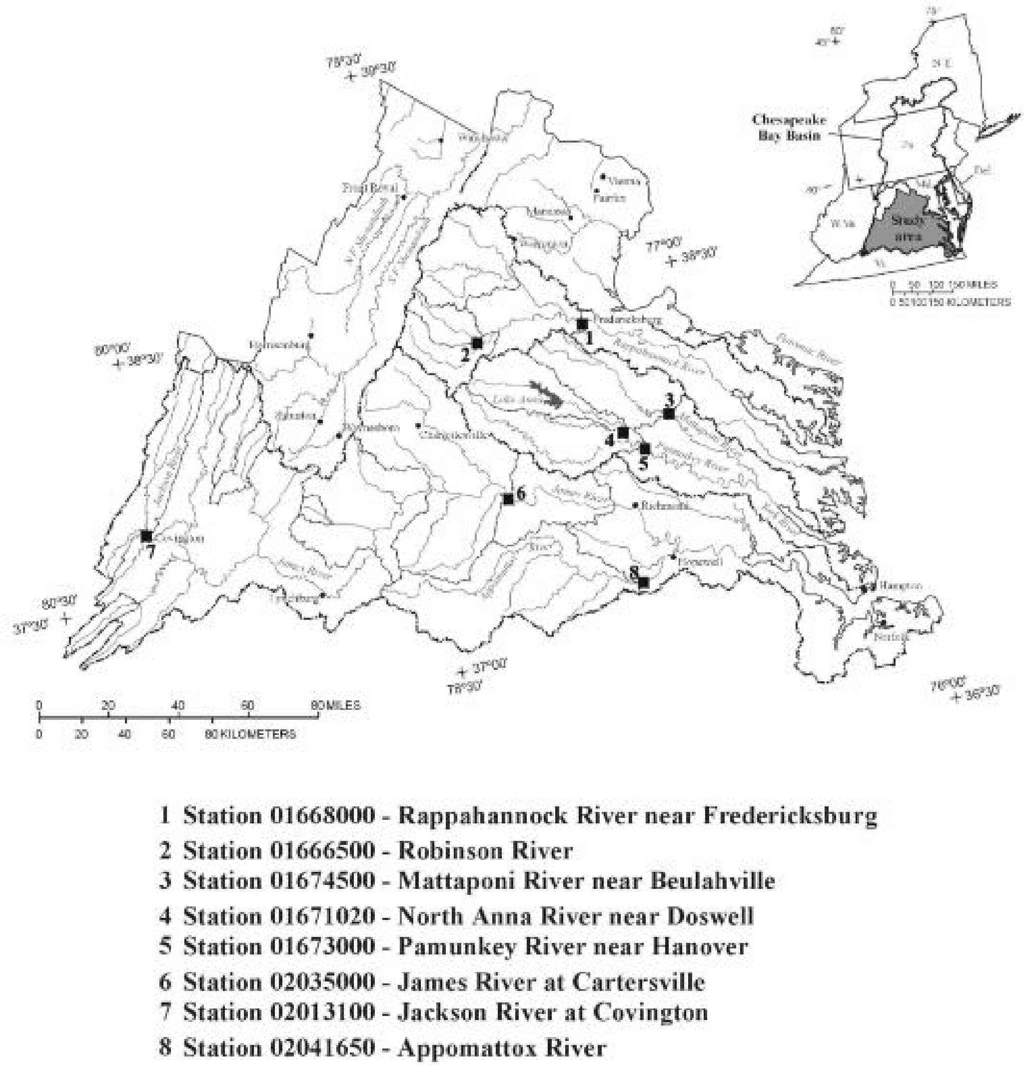


Figure 2-1. Locations of the USGS sampling stations at and above the fall-line in each of the Virginia tributaries.

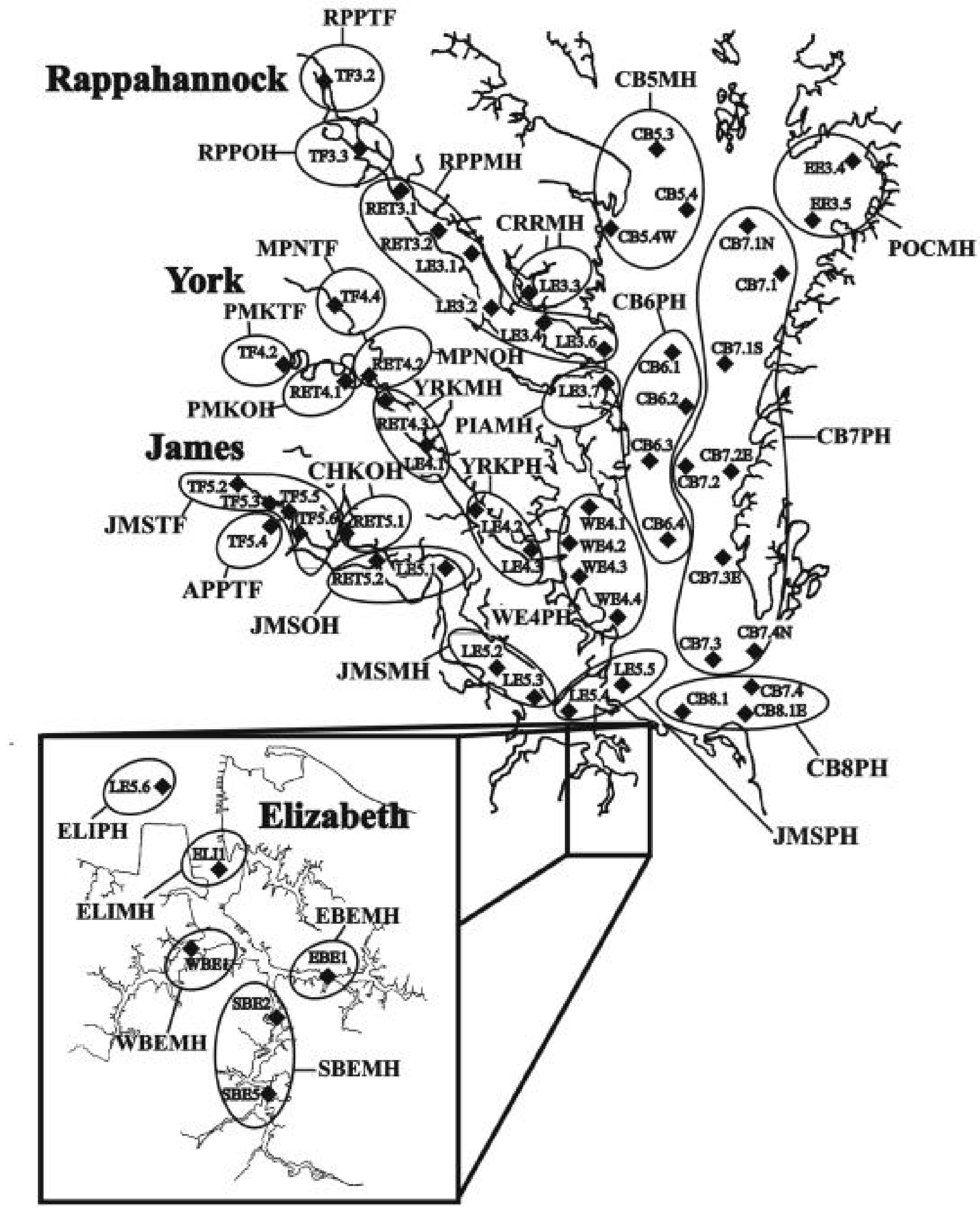


Figure 2-2. Map showing the locations of the water quality monitoring stations in the Virginia tributaries and the Lower Chesapeake Bay Mainstem used in the statistical analyses. Also shown are ellipses that delineate the Chesapeake Bay Program segmentation scheme .

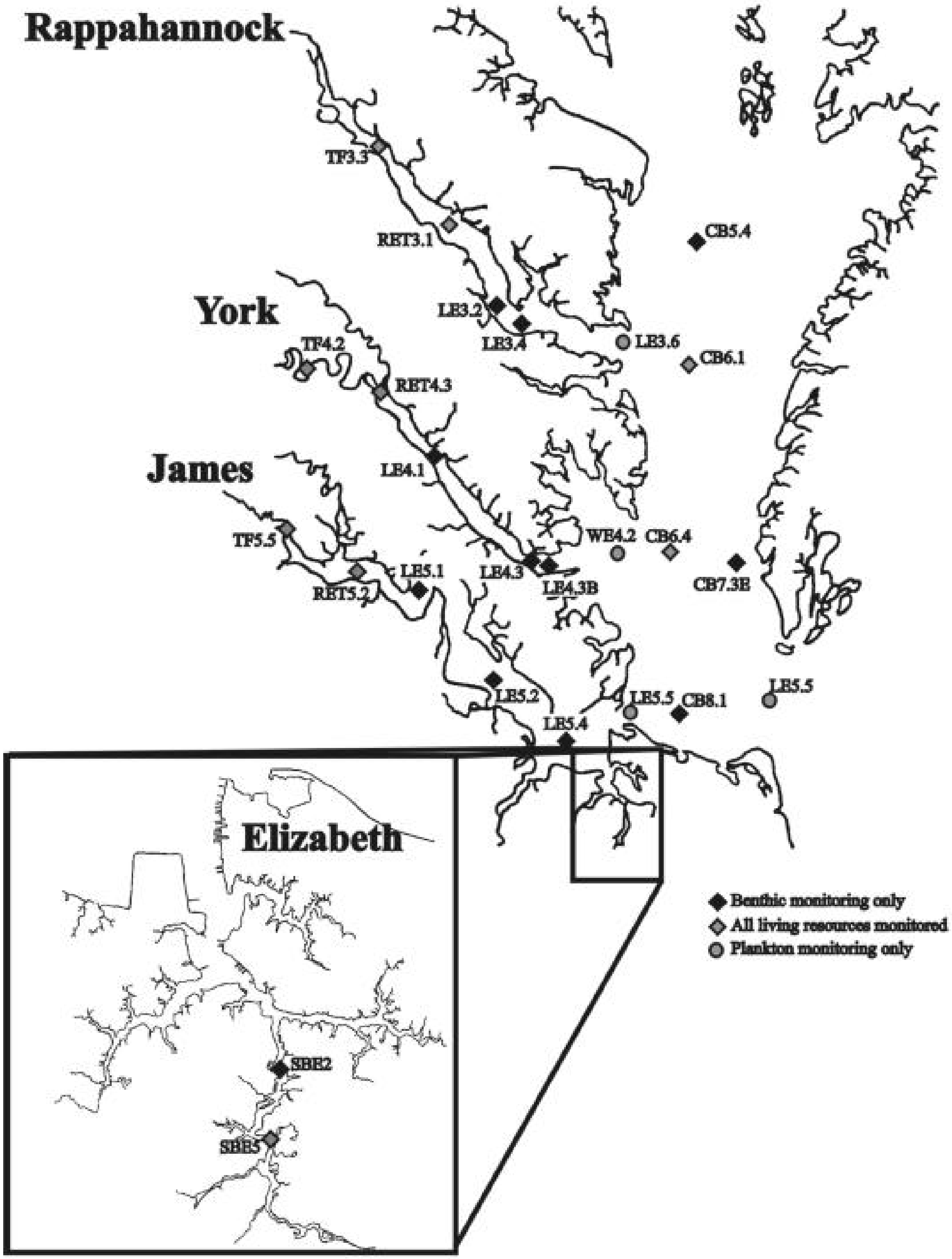


Figure 2-3. Location of living resource monitoring stations in the Virginia tributaries and the Lower Chesapeake Bay Mainstem.

Table 2-1. Definitions of seasonal time periods for status and trend analyses conducted for of the tidal monitoring programs. A “x” indicates the analysis was conducted for the season and parameter group combination while a “-“ indicates that no analysis was conducted. Note that benthic status and trend analyses were conducted on data collected from June 15 through September 30.

		Water Quality			Plankton		Benthos	
Season	**Definition**	**Status**	**Trend**	**SAV Goals**	**Status**	**Trend**	**Status**	**Trend**
Annual	Entire year	x	x	-	x	x	-	-
SAV1	March through May and September through November	x	x	x	x	x	-	-
SAV2	April through October	x	x	-	x	x	-	-
Summer1	June through September	x	x	-	x	x	x*	x*
Summer2	July through September	x	x	-	x	x	-	-
Spring1	March through May	x	x	-	x	x	-	-
Spring2	April through June	x	x	-	x	x	-	-
Fall	October through December	-	x	-	x	x	-	-
Winter	January and February	-	x	-	x	x	-	-

Table 2-2. Habitat requirements for growth and survival of SAV (from Batuik el al., 1992; 2000).

Salinity Regime	**SAV Growth Season**	**Percent Light at Leaf**	**Total Suspended Solids (mg/l)**	**Chlorophyll *a* (F g/l)**	**Dissolved Inorganic Nitrogen (mg/l)**	**Dissolved Inorganic Phosphorus (mg/l)**
Tidal Freshwater	Apr.-Oct.	<2	<15	<15	none	<0.02
Oligohaline	Apr.- Oct.	<2	<15	<15	none	<0.02
Mesohaline	Apr.-Oct.	<1.5	<15	<15	<0.15	<0.01
Polyhaline	Mar.-May, Sep.-Nov.	<1.5	<15	<15	<0.15	<0.01

Chapter 3. York River Basin

I. Executive Summary

A. Summary of Basin Characteristics

The York River watershed consists of approximately 8,468 km^2. Forested and agricultural lands are the most abundant in the watershed accounting for nearly 61% and 21% of the total land cover in the basin, respectively. All other land use types each account for less than 10% of the remaining land in the basin. Approximately 6,062 km of the over 16,117 km of streambanks and shoreline within the watershed has a 30 m minimum riparian forest buffer. The York River watershed has an estimated human population of 372,488 with an overall population density of 47.63 individuals per km^2. Major population centers within the watershed include Ashland, West Point, and Hampton.

In 2000, agricultural non-point sources accounted for 1,446,051 kg/yr (37%) of total nitrogen loadings to the York River while urban non-point, mixed open non-point and point sources in combination account for 1,677,837 kg/yr (42%) in approximately equal proportions. Agricultural non-point sources accounted for 144,696 kg/yr (40%) of total phosphorus loadings while mixed open and point sources accounted for 153,768 kg/yr (42%). In 2001, total point source loadings of total nitrogen and total phosphorus in the York River watershed were 502,801 kg/yr and 84,618 kg/yr, respectively.

Daily freshwater flow at the fall-line in the Mattaponi ranged from a minimum of 0.01 m^3/sec to a maximum of 220.31 m^3/sec for the period of January 1, 1985 through December 32, 2002. Grand mean flow at the fall-line was 13.63 m^3/sec. Daily freshwater flow at the fall-line in the Pamunkey was higher ranging from a minimum of 0.68 m^3/sec to a maximum of 577.66 m^3/sec and with an grand mean flow of 26.71 m^3/sec. Figures 3-1 to 3-9 provide summary information of basin characteristics of the York River.

B. Summary of Status and Long Term Trends

Figures 3-10 and 3-11 provide summaries of water quality status and trend analyses for the York River. Status of surface and bottom total nitrogen was good in the Upper Pamunkey River, the Upper and Lower Mattaponi River, and the Lower York River(PMKTF, MPNTF, MPNOH and YRKPH). The status of the surface and bottom total nitrogen was fair in Mobjack Bay (MOBPH). The status of the surface and bottom total nitrogen was good and poor respectively in the Lower Pamunkey River (PMKOH), and fair and poor respectively in the Middle York River (YRKMH). Status of the surface and bottom dissolved inorganic nitrogen was good for all segments of the York River, with the exception of the surface dissolved inorganic nitrogen for the Middle York River segment (YRKMH) where the status was fair. Status of surface and bottom total and dissolved inorganic phosphorus was either poor or fair in all segments except for (1) surface and bottom total phosphorus and dissolved inorganic phosphorus in the Upper Pamunkey River, (2) the Upper Mattaponi River (segments PMKTF and MPNTF) and for bottom total phosphorus and surface and bottom dissolved inorganic in Mobjack Bay (MOBPH). Status for surface chlorophyll *a* was good for the Upper Pamunkey River, Upper Mattaponi

River and Mobjack Bay (PMKTF, MPNTF, and MOBPH), fair for the Lower Pamunkey River and Lower Mattaponi River (PMKOH and MPNOH), and poor for the Middle and Lower York River (YRKMH and YRKPH). Status for surface and bottom total suspended solids and secchi depth was fair or poor in most segments. Status for bottom dissolved oxygen was fair or good in all segments of the York River. In the Pamunkey River and the Mattaponi River segments, the majority of parameters either did not meet the SAV habitat requirement or were borderline; except chlorophyll *a* in the tidal fresh portions of each river. In the Middle York River (YRKMH) only dissolved inorganic nitrogen and chlorophyll *a*, which was borderline, met the SAV habitat requirements. In contrast, in the Lower York River (YRKPH) and Mobjack Bay (MOBPH) all parameters except one met the SAV criteria.

A degrading trend in bottom total nitrogen was detected in the Lower Pamunkey River (PMKOH) while improving trends in surface and bottom total nitrogen were detected in Mobjack Bay (MOBPH). No other trends in nitrogen parameters were consistent between the pre- and post-method change periods. Widespread degrading trends in phosphorus parameters that were consistent between the pre- and post-method change periods were detected throughout the York River in every segment except Mobjack Bay where no trends in phosphorus were detected. Improving trends in surface and bottom dissolved inorganic phosphorus were detected in Upper Pamunkey River and Upper Mattaponi River (PMKTF and MPNTF) and were consistent between the pre- and post-method change period. Degrading trends in secchi depth and/or total suspended solids were detected in the Upper Pamunkey River (PMKTF) and the Upper Mattaponi River (MPNTF), as well as, the Middle York River (YRKMH)and Lower York River (YRKPH). Improving trends detected in the York River were localized in Mobjack Bay and included trends in surface and bottom total nitrogen, surface chlorophyll *a* surface and bottom total suspended solids and bottom dissolved oxygen.

Figures 3-12 to 3-14 provide summaries of living resource status and trend analyses for the York River. Many of the phytoplankton categories in the York River have poor or fair status. Prominent is the poor status associated with total phytoplankton biomass, the phytoplankton abundance to biomass ratio, and the biomass of the autotrophic picoplankton, dinoflagellates and cyanobacteria. Total phytoplankton biomass and abundance show increasing trends, along with the diatoms and chlorophytes. Of concern is the poor status for cyanobacteria in the middle and lower reaches of the river, with increasing biomass and abundance trends present at each station. Dinoflagellate blooms are common during the summer and early fall months in the lower reach of the river, which in the past have included toxin producing flora. The phytoplankton remains a diatom dominant system, but this influence is being challenged by increasing concentrations of cyanobacteria, in addition to increased threats to the trophic status by these summer dinoflagellate blooms.

Status of copepod nauplii was fair in the Upper Pamunkey River (PMKTF), good in the Middle York River (YRKMH) and poor in Mobjack Bay (MOBPH). Status of rotifer abundance was poor in all segments except the Upper Pamunkey River (RPPTF) where it was good. Degrading trends in copepod nauplii and rotifer abundance were detected in the Middle York River and Mobjack Bay, respectively.

In the tidal freshwater Pamunkey River (PMKTF), benthic community status was good with improving trends in species diversity and abundance. In the mesohaline York River (YRKMH), benthic community status was marginal at both stations. The was a significant degrading trends in the B-IBI at Station RET4.3. In the Lower York River (YRKPH), benthic community status was good at stations LE4.3 and LE4.3B.

C. Summary of Major Issues in the Basin

With respect to nutrients, phosphorus appears to be the predominant problem in the York River. Relative status of these parameter was generally fair or poor in all of these segments. In addition, the SAV habitat criteria for dissolved inorganic phosphorus was not met in any segments of the York River except Mobjack Bay. Finally, long-term degrading trends were detected in at least one phosphorus parameter in every segment of the York River except Mobjack Bay (MOBPH)

Water clarity is also a widespread problem in the York River. Status of secchi was poor in three of the seven segments in the York River and only fair in the remaining four segments. The SAV habitat requirement for this parameter was met only in the Lower York River (YRKPH) and in Mobjack Bay (MOBPH). Status of surface and bottom total suspended solids was fair or poor in every segment of the York River except the Upper Mattaponi where it was good and the SAV habitat requirement for this parameter was not met in all segments except the Lower York River (YRKPH) and Mobjack Bay (MOBPH). Degrading trends in secchi depth and/or total suspended solids were detected in all segments of the York River except the Lower Pamunkey River (PMKOH) and Mobjack Bay (MOBPH).

Two major concerns associated with the phytoplankton trends exist. These are increased concentrations of cyanobacteria and dinoflagellates within the river. Degrading trends in rotifer abundance were detected in Mobjack Bay (MOBPH) and the Middle York River (YRKMH). The degrading trends in the Middle York River may be related to degrading trends in phosphorus, chlorophyll *a* and/or suspended solids. Alternatively, increasing trends in surface salinity may be affecting the trends in these parameters in both segments. A mesohaline benthic monitoring station showed a degrading trend in the B-IBI while the previously degraded to marginal status of the deep water areas of the polyhaline York River (YRKPH) improved to good (LE4.3B).

II. Management Recommendations

The cause of the poor status and trends in phosphorus and water clarity is uncertain. It is likely that increases in the phosphorus load and sediment load is occurring from the rapid urbanization in WSM segments 260 & 590, resulting in more NPS run off containing phosphorus and sediment. These problems may also be related at least in part due to the increase in recent years of point source phosphorus loadings in both the Pamunkey and Mattaponi Rivers. The source of water clarity problem is unclear. It may be the result of increased sediment input to the water collumn from a variety of sources, including strong tidal resuspension and shoreline erosion. Alternatively, the decrease in water clarity may be caused by an increase in the abundance of phytoplankton in the water column. Degrading (increasing) trends in cyanobacterial abundance were detected at all stations monitored in the York River and degrading trends in surface chlorophyll *a* concentrations were also detected in three segments of the York River. The increases in point source phosphorus loads observed above the fall-line in the Pamunkey River could also contribute to potential increases in phytoplankton. It is recommended that additional controls on both point source & NPS be initiated for phosphorus reduction in this section of the Pamunkey to alleviate any potential problem above the fall line. Overall, there is a dominance of non-point source nutrient inputs to the York system as a whole and these non-point sources should be examined for actions which can be taken to reduce their loads.

Freshwater input to both the Pamunkey and Mattaponi was lower during the past three years than in previous years. Low flows could also adversely affect both nutrient levels and water clarity by reducing the flushing rates in the river such that nutrient, sediment and/or phytoplankton concentrations increase as a result.

A more thorough investigation of existing data sets may help to identify potential sources of the water clarity problems. An analysis of trends in both the fixed and volatile components of total suspended solids along with a statistical analysis of potential relationships between secchi depth and various environmental factors such as suspend solids concentrations, flow regime and phytoplankton concentrations is recommended. Continued monitoring of the status of the phytoplankton community is a prime concern to determine changes in the balance of favorable and non-favorable dominant taxa within the populations. Any further dominance in the cyanobacteria or dinoflagellates should be documented in relation to river locations, and related water quality conditions. Phosphorus and suspended solid problems in the York River may explain the degrading trends in and poor status of microzooplankton indicators in the lower segments of the York River (YRKMH and MOBPH).

With respect to benthic communities the problem was located in the Middle York River (YRKMH). In the Middle York River benthic community status was marginal at both stations (RET4.3 and LE4.1) with a degrading trend in the B-IBI at Stations RET4.3. Additional information is required before conclusions regarding management actions related to the benthos can be made.

III. Overview of Basin Characteristics

The York River watershed consists of approximately 8,468 km^2 and extends 225 km from the headwaters of the Pamunkey and Mattaponi rivers in Orange and Louisa counties to Yorktown, Virginia where it empties into Chesapeake Bay. Human population in the York River watershed increased from 324,036 individuals in 1990 to 372,488 in 2000 (Figure 3-1a) and is projected to reach over 450,000 by 2020. Overall population density was 47.63 individuals per km^2. Population density within the York River watershed ranged from 20.59 individuals per km^2 within the Mattaponi sub-watersheds to over 500 individuals per km^2 in the Poquoson (lower portion of the York River) sub-watershed (Figure 3-1b). Major population centers within the watershed include Ashland, Gloucester Point, Hampton, and West Point.

Forested and agricultural lands are the most abundant land-use types in the watershed accounting for nearly 61% and 21% of the total land cover in the basin, respectively. All other land use types each account for less than 10% of the remaining land in the basin. Approximately 6,062 km of the over 16,117 km of streambanks and shoreline within the watershed has a 30 m minimum riparian forest buffer. Forested land decreases substantial moving downstream from the Pamunkey and Mattaponi rivers both in terms of total area and percent of the total area within the sub-watersheds while urban land increases downstream (Figures 3-2a-b).

In 2000, agricultural non-point sources accounted for 1,446,051 kg/yr (37%) of total nitrogen loadings to the York River while urban non-point, mixed open non-point and point sources in combination account for 1,677,837 kg/yr (42%) in approximately equal proportions (Figure 3-3a). Agricultural non-point sources accounted for 144,696 kg/yr (40%) of total phosphorus loadings while mixed open and point sources accounted for 153,768 kg/yr (42%) in nearly equal amounts (Figure 3-3b). The primary source of sediment loads to the York River is non-point run-off from agricultural and forest lands which account for 63,503,300 kg/yr (54%) and 29,937,270 kg/yr (25%) of the total load, respectively. The remaining sources of sediment loads contribute little to the total load (Figure 3-3c).

From 1985 through 1988, point source loadings of total nitrogen decreased substantially but during the following decade increased to levels above those observed in 1985. This increasing trend in point source nitrogen may be reversing as indicated by the drop in loadings during 2000 and 2001 (Figure 3-4a). Total phosphorus loadings substantially decreased immediately following the phosphate ban from over 200,000 kg/yr in 1985 to less than 70, 000 kg/yr in 1990. Although there appears to be a small increasing trend in the data point source loadings to the watershed have remained relatively stable at values less than 100,000 kg/yr (Figure 3-4b).

In 2001, point source loads of both total nitrogen and total phosphorus were concentrated above the fall-line in the Pamunkey River, and within the Mattaponi River, and Poquoson sub-watersheds. Point source loadings within other sub-watersheds are negligible (Figure 3-5a-b). Plots of annual point source total nitrogen loadings to these three sub-watersheds showed a fairly consistent increase in nitrogen loadings above the fall-line in the Pamunkey and in the Poquoson sub-watershed from 1985 to 2001 (Figure 3-6). Following the phosphate ban, point source phosphorus loadings decreased substantially and have remained at consistently low levels in four of the five sub-watersheds of the York River (Figure 3-7). However, point source loadings of this nutrient are increasing above the fall-line in the Pamunkey River (Figure 3-7a).

Daily freshwater flow at the fall-line in the Mattaponi ranged from a minimum of 0.01 m^3/sec to a maximum of 220.31 m^3/sec for the period of January 1, 1985 through December 32, 2002. Grand mean flow at the fall-line was 13.63 m^3/sec. Daily freshwater flow at the fall-line in the Pamunkey was higher ranging from a minimum of 0.68 m^3/sec to a maximum of 577.66 m^3/sec and with an grand mean flow of 26.71 m^3/sec. Peaks in monthly mean freshwater flow for the last four years in both the Pamunkey and Mattaponi rivers were generally less than those of previous years peaks (Figure 8a-b). Annual mean flow during the last four years in both the Pamunkey and Mattaponi rivers was lower than the respective grand mean flow for each tributary (Figure 9a-b).

IV. Overview of Monitoring Results

Status of surface and bottom total and dissolved inorganic nitrogen was either good or fair in every segment of the York River, except for a poor status for bottom total nitrogen in the Lower Pamunkey and the Middle York Rivers (PMKOH and TRKMH). Status of surface and bottom total and dissolved inorganic phosphorus was either poor or fair in all segments except for surface and bottom total and dissolved inorganic phosphorus in the Upper Pamunkey and the Upper Mattaponi Rivers (segments PMKTF and MPNTF) and for bottom total phosphorus and surface and bottom dissolved inorganic phosphorus in Mobjack Bay (MOBPH). Status for surface chlorophyll *a* was good for the Upper Pamunkey River, Upper Mattaponi River and Mobjack Bay (PMKTF, MPNTF, and MOBPH), fair for the Lower Pamunkey River and Lower Mattaponi River (PMKOH and MPNOH), and poor for the Middle and Lower York River (YRKMH and YRKPH). Status for surface and bottom total suspended solids and secchi depth was fair or poor in most segments, with the exception of surface and bottom total suspended solids in the Upper Mattaponi River (MPNTF) and bottom total suspended solids in Mobjack Bay (MOBPH) where the status was good (Figure 3-10 and 3-11). Status for bottom dissolved oxygen was good or fair in all segments of the York River. In the Pamunkey River and the Mattaponi River segments the majority of parameters either did not meet the SAV habitat requirement or were borderline, with the exception of chlorophyll *a* which met SAV habitat requirements in all segments of these rivers. In the Middle York River (YRKMH) only dissolved inorganic nitrogen and chlorophyll *a*, which was borderline, met the SAV habitat requirements. In contrast, in the Lower York River (YRKPH) and Mobjack Bay (MOBPH) nearly all parameters met the SAV criteria.

Degrading trends in total phosphorus were detected that were consistent for pre- and post-method change data for the Upper Pamunkey River (PMKTF), the Upper Mattaponi River (MKNTF), the Middle York River (YRKMH) and the Lower York River (YRKPH). Consistent degrading trends in the pre- and post-method periods were detected in dissolved inorganic phosphorus in the Lower Pamunkey River (PMKOH), the Lower Mattaponi River, the Middle York River (YRKMH) and the Lower York River (YRKPH). Improving trends in surface and bottom dissolved inorganic phosphorus that were consistent between pre- and post-method change periods were detected in the Upper Pamunkey River (PMKTF) and the Upper Mattaponi River (MPNTF). Degrading trends in surface chlorophyll *a* were detected in the Lower Pamunkey River (PMKOH), the Middle York River (YRKMH) and the Lower York River (YRKPH). Degrading trends in either secchi depth or total suspended solids were detected in all segments except the Lower Pamunkey River (PMKOH) and Mobjack Bay (MOBPH). Improving trends in surface and bottom total nitrogen, surface chlorophyll a, surface and bottom total suspended solids and bottom dissolved oxygen were detected in Mobjack Bay (MOBPH).

The monitoring program has identified a significant pattern of increasing trends among two categories of populations generally associated with degrading water quality conditions and a less favorable food source for river faunal populations. Although diatoms are still dominant in these waters, this position could be challenged in sections of this river if cyanobacteria and dinoflagellate development increases (Figure 3-12).

Status of copepod nauplii was fair in the Upper Pamunkey River (PMKTF), good in the Middle York River (YRKMH) and poor in Mobjack Bay (MOBPH). Status of rotifer abundance was poor in all segments except the Upper Pamunkey River (RPPTF) where it was good. A degrading trend in copepod nauplii was detected in the Middle York River and a degrading trend in rotifer abundance was detected in Mobjack Bay (Figure 3-13).

In the tidal freshwater Pamunkey River (PMKTF) benthic community status was good with improving trends in species diversity and abundance. In the mesohaline York River benthic community status was marginal at both stations (RET4.3 and LE4.1) with a degrading trend in the B-IBI at Stations RET4.3. In the Lower York River (YRKPH), benthic community status was good at stations LE4.3 and LE4.3B and there was a significant improving trend in the B-IBI at station LE4.3B. (Figure 3-14).

V. Detailed Overview of Status and Trends

A. Fall-Line

In the Pamunkey River at Hanover, degrading trends in flow adjusted and flow weighted concentrations total nitrogen, nitrates-nitrites (fixed), total phosphorus, and dissolved inorganic phosphorus. Degrading trends were also detected in loadings of dissolved inorganic phosphorus and total suspended solids at this station (Table 3-1). A decreasing trend in freshwater flow were detected at this station (Table 3-1).

In the Mattaponi River near Beulahville, improving trends in flow adjusted concentrations, flow weighted concentrations and loadings of total nitrogen, nitrates-nitrites, and total phosphorus were detected. Improving trends were also detected in loadings of dissolved inorganic phosphorus and in flow weighted concentrations and loadings of total suspended solids at this station (Table 3-1). In the North Anna River at Doswell, improving trends in flow adjusted concentrations, flow weighted concentrations and loadings of ammonia and flow weighted concentrations and loadings of nitrates-nitrites and nitrates were detected at this station. Improving trends in flow adjusted concentrations, flow weighted concentrations and loadings of total phosphorus were detected at this station. Degrading trends in flow adjusted and flow weighted concentrations of total Kjeldahl nitrogen and flow adjusted total suspended solids (Table 3-1).

B. Mobjack Bay (MOBPH)

<u>1. Water quality for living resources</u>

a) Nutrient parameters

Status was fair for surface and bottom total nitrogen. Status was good for surface and bottom dissolved inorganic nitrogen. Status was good for all phosphorus parameters, except for surface total phosphorus for which the status was fair (Table 3-2). Significant improving trends in surface and bottom total nitrogen were detected in this segment. Although there were statistically significant trends in several other parameters, none of these trends had a slope that was above zero (Table 3-3).

b) Non-nutrient parameters

Status was good for surface chlorophyll *a*, bottom total suspended solids and bottom dissolved oxygen but fair for surface total suspended solids and poor for secchi depth (Table 3-2). Improving trends were detected in surface chlorophyll *a*, surface and bottom total suspended solids and bottom dissolved oxygen. A significant increasing trend was also detected in surface salinity (Table 3-3).

<u>2. Water quality for SAV</u>

a) SAV habitat requirements

All parameters meet the SAV habitat requirements (Table 3-4).

b) Nutrient parameters

Improving trends were detected in surface total nitrogen and surface dissolved inorganic nitrogen (Table 3-5).

c) Non-nutrient parameters

Although there is a significant improving trend in surface total suspended solids, a degrading trend in secchi depth was also detected (Table 3-5).

<u>3. Living resources</u>

Fair to poor status represented the categories of total biomass, biomass to abundance ratio, diversity, productivity, and the biomass of diatoms, dinoflagellates, cyanobacteria, picoplankton, and the prokaryote to eukaryote ratio. No significant trends predominated among the categories, except for favorable trends in productivity, diatom biomass, and chlorophyte biomass. Negative trends were associated with cyanobacteria abundance and biomass, and cryptophyte biomass. Although no significant trend was associated with the dinoflagellates, this is a region of common dinoflagellate blooms during summer and fall (Figure 3-12). Status of both microzooplankton bioindicators were poor and a degrading trend was detected in rotifer abundance. Decreasing trends were also detected in tintinnid and polychaeta larval abundance (Figure 3-13). Benthic monitoring is not conducted within this segment and it is recommended that monitoring of benthic communities be conducted within this segment (Figure 3-14).

C. Polyhaline York River (YRKPH- Lower York)

1. Water quality for living resources

a) Nutrient parameters

Status of all nitrogen parameters was good. Status for surface and bottom total phosphorus was fair and poor, respectively while the status of both surface and bottom dissolved inorganic phosphorus was fair. Significant degrading trends in surface total phosphorus and surface and bottom dissolved inorganic phosphorus were detected that were consistent between the pre- and post-method change periods. Significant differences in trends between pre- and post-method change periods were detected in bottom total nitrogen, bottom dissolved inorganic nitrogen, and bottom total phosphorus. Although a significant degrading trend in bottom total nitrogen was detected prior to the method change, no significant trend in this parameter was detected in the post-method change period. No significant trend in bottom dissolved inorganic nitrogen was detected in the pre-method change period but a significant degrading trend was detected for this parameter after the method change. Before the method change, there was a significant trend in bottom total phosphorus but after the method change no significant trend was detected in this parameter.

b) Non-nutrient parameters

Status of surface chlorophyll *a* , bottom total suspended solids, and secchi depth was poor while the status of surface total suspended solids and bottom dissolved oxygen was fair (Table 3-5). Degrading trends in bottom total suspended solids and secchi depth were detected in this segment (Table 3-6).

2. Water quality for SAV

a) SAV habitat requirements

All parameters except for surface dissolved inorganic phosphorus met the SAV habitat requirements (Table 3-8).

b) Nutrient parameters

An improving trend in surface dissolved inorganic nitrogen was detected that was consistent between the pre- and post-method change periods. Degrading trends in surface total nitrogen and surface total phosphorus were detected only in the pre-method change period. A degrading trend in surface dissolved inorganic phosphorus was detected in the post-method change period (Table 3-9).

c) Non-nutrient parameters

A degrading trend was detected in secchi depth during the SAV growing season (Table 3-9).

3. Living resources

Phytoplankton and zooplankton monitoring is not conducted within this segment. Benthic community status was good at both stations. The previously degraded to marginal status of the deep water areas of the polyhaline York River (YRKPH) improved to good (LE4.3B) and there was a significant improving trend in the B-IBI (Figure 3-14).

D. Mesohaline York River (YRKMH - Middle York)

1. Water quality for living resources

a) Nutrient parameters

Status for surface and bottom total nitrogen was fair and poor, respectively. The status of surface and bottom dissolved inorganic nitrogen was fair and good, respectively. Status of all phosphorus parameters was poor. Significant degrading trends in surface and bottom total and dissolved inorganic phosphorus were detected that were consistent between the pre- and post-method change periods. A degrading trend in bottom total nitrogen was detected during the pre-method period while no significant trend was detected during the post-method change period.

b) Non-nutrient parameters

The status of surface chlorophyll *a* and all indicators of water clarity was poor. The status of dissolved oxygen was good. Degrading trends in surface chlorophyll a and bottom total suspended solids were detected along with an improving trend in summer bottom dissolved oxygen and an increasing trend in surface salinity.

2. Water quality for SAV

a) SAV habitat requirements

Although surface dissolved inorganic nitrogen and surface chlorophyll *a* met the SAV habitat requirements, all other parameters exceeded their respective criteria (Table 3-12).

b) Nutrient parameters

A degrading trends in surface dissolved inorganic phosphorus was detected that was consistent between the pre- and post-method changes periods. Significant degrading trends were detected in pre-method change period for surface total nitrogen and surface total phosphorus that were not detected during the post-method change period (Table 3-13).

c) Non-nutrient parameters

No significant trends were detected in chlorophyll *a*, water clarity, water temperature or salinity in this segment during the SAV growing season (Table 3-13).

3. Living resources

In this region the total phytoplankton biomass and abundance show increasing trends along with increasing biomass of diatoms, chlorophytes, cryptophytes, and cyanobacteria. The status of dinoflagellate biomass, picoplankton biomass, and cyanobacteria biomass and abundance is poor. No significant trends are associated with productivity, diversity, or the prokaryote to eukaryote ratio (Figure 3-12). This region is also influenced by greater prominence of cyanobacteria. Status of copepod nauplii abundance status was good, however, there was a significant degrading trend in this bioindicator. Status of rotifer abundance was poor and there was no significant trend in this parameter. Decreasing trends in cladoceran and tintinnid abundance was also detected in this segment (Figure 3-13). Benthic community status was marginal at both benthic monitoring stations with a degrading trend in the B-IBI at Station RET4.3 (Figure 3-14).

E. Oligohaline Pamunkey River (PMKOH - Lower Pamunkey)

1. Water quality for living resources

a) Nutrient parameters

Status of all nitrogen parameters was good except for bottom nitrogen for which the status was poor.
Status of all phosphorus parameters was poor except for surface total phosphorus for which the status was fair. Significant degrading trends in bottom total nitrogen and bottom dissolved inorganic phosphorus were detected that were consistent between the pre- and post-method periods. Significant differences in trends between pre- and post-method change periods were detected in surface total nitrogen, surface and bottom total phosphorus and surface dissolved inorganic phosphorus. For each of these parameters a degrading trend was detected in the pre-method period that was not detected in the post-method period.

b) Non-nutrient parameters

Status of surface chlorophyll *a* and secchi depth was fair while the status of surface and bottom total suspended solids was poor. Status of bottom dissolved oxygen was fair. A degrading trend in surface chlorophyll *a* was detected and accompanied by an improving trend in secchi depth and increasing trends in surface and bottom salinity.

2. Water quality for SAV

a) SAV habitat requirements

All parameters except surface chlorophyll *a* failed to meet the SAV habitat criteria (Table 3-16).

b) Nutrient parameters

There were significant differences in trends between the pre- and post-method change periods for all parameters collected during the SAV growing season. Degrading trends were detected in all surface nutrient parameters during the pre-method change period but none of these trend were detected during the post-method change period (Table 3-17).

c) Non-nutrient parameters

An increasing trend in surface salinity was detected in this segment (Table 3-17).

3. Living resources

Living resource monitoring is not conducted within this segment.

F. Tidal Freshwater Pamunkey River (PMKTF - Upper Pamunkey)

1. Water quality for living resources

a) Nutrient parameters

Status of all nitrogen and phosphorus parameters was good except surface total nitrogen for which the status was fair. Significant improving trends in surface and bottom dissolved inorganic phosphorus were detected that were consistent between the pre- and post-method change periods. Significant degrading trends were detected in surface and bottom total phosphorus that were consistent between the pre- and post-method change periods. A significant degrading trend in surface total nitrogen was detected only in the post-method change period (Table 3-19).

b) Non-nutrient parameters

Status of surface chlorophyll *a* was good. Status of surface and bottom total suspended solids was poor and fair, respectively. Status of secchi depth was fair. Status of bottom dissolved oxygen was good. A degrading trend in surface total suspended solids was detected along with increasing trends in surface and bottom water temperature and salinity.

2. Water quality for SAV

a) SAV habitat requirements

Although the SAV habitat requirements for surface dissolved inorganic phosphorus and surface chlorophyll *a* were met, both surface total suspended solids and secchi depth failed to meet their respective criteria (Table 3-20).

b) Nutrient parameters

A degrading trend that was consistent between pre- and post-method change periods was detected in surface total nitrogen. An improving trend in surface dissolved inorganic phosphorus was also detected that was consistent between pre- and post-method change periods (Table 3-21).

c) Non-nutrient parameters

A degrading trend in surface total suspended solids was detected in this segment. Increasing trends in surface water temperature and surface salinity were also detected (Table 3-21).

3. Living resources

The over all status in this section of the river is mainly poor to fair. Poor status is found in the biomass of diatoms, dinoflagellates, and picoplankton. Cyanobacteria abundance and biomass status are both fair. Trends of increased biomass are associated with the diatoms, cyanobacteria, chlorophytes, and cryptophytes. There is no significant trend for productivity, diversity, biomass to abundance ratio, or the prokaryote to eukaryote ratio. There is an overall increase in both phytoplankton abundance and biomass (Figure 3-12). Although not a common place for blooms, common bloom producing cyanobacteria are found in this region. Rotifer abundance status is good while copepod nauplii abundance status was fair. Although there were no significant trends in copepod nauplii or rotifer abundance, a decreasing trend in cladoceran abundance was detected in this segment (Figure 3-13). Benthic community status was good with improving trends in species diversity and total abundance (Figure 3-14).

G. Oligohaline Mattaponi River (MPNOH - Lower Mattaponi)

1. Water quality for living resources

a) Nutrient parameters

Status of all nitrogen parameters was good. Status of all phosphorus parameters was poor except bottom total phosphorus for which the status was fair (Table 3-22). Significant degrading trends in surface and bottom dissolved inorganic were detected that were consistent between the pre- and post-method change periods. Significant differences in trends were detected between the pre- and post-method change periods for surface total nitrogen, bottom dissolved inorganic nitrogen and surface and bottom total phosphorus. For all of these parameters, significant degrading trends were detected in the pre-method change period that were not detected after the method change occurred (Table 3-23).

b) Non-nutrient parameters

Status of all non-nutrient parameters was fair except for bottom total suspended solids for which the status was poor (Table 3-22). A degrading trend in surface chlorophyll *a* was detected in this segment along with increasing trends in surface water temperature and surface and bottom salinity (Table 3-23).

2. Water quality for SAV

a) SAV habitat requirements

All parameters except surface chlorophyll *a* failed to meet the SAV habitat requirements (Table 3-24).

b) Nutrient parameters

Degrading trends were detected only in the pre-method change period for all surface nutrient parameters (Table 3-25).

c) Non-nutrient parameters

Degrading trends were detected in surface chlorophyll *a* and surface total suspended solids along with an increasing trend in surface salinity (Table 3-25).

3. Living resources

Living resource monitoring is not conducted within this segment.

H. Tidal Freshwater Mattaponi River (MPNTF - Upper Mattaponi)

1. Water quality for living resources

a) Nutrient parameters

Status of all nutrient parameters was good (Table 3-26). A significant improving trend in bottom dissolved inorganic phosphorus was detected that were consistent between the pre- and post-method change periods. A significant degrading trend in bottom total phosphorus was detected that was consistent between the pre- and post-method change periods. A degrading trend in surface total phosphorus was detected during the pre-method change period while no significant trend was detected during the post-method change period (Table 3-27).

b) Non-nutrient parameters

Status of all non-nutrient parameters was good except secchi depth for which the status was fair (Table 3-26). Degrading trends in surface total suspended solids and secchi depth were detected along with increasing trends in surface and bottom water temperature and salinity (Table 3-27).

2. Water quality for SAV

a) SAV habitat requirements

Although the SAV habitat requirements were met for surface dissolved inorganic phosphorus and secchi depth, the criteria were not met for surface chlorophyll *a* and surface total suspended solids (Table 3-28).

b) Nutrient parameters

No trends detected were consistent between the pre- and post-method change period. An improving trends in surface total nitrogen, and degrading trends in surface dissolved inorganic nitrogen and surface total phosphorus, and surface dissolved inorganic phosphorus were detected in the pre-method change period and none of these trends were detected in the post-method change period (Table 3-29). An improving trend in surface dissolved inorganic phosphorus was detected only during the post-method change period (Table 3-29).

c) Non-nutrient parameters

Increasing trends were detected in surface water temperature and surface salinity (Table 3-29).

3. Living resources

Living resource monitoring is not conducted within this segment.

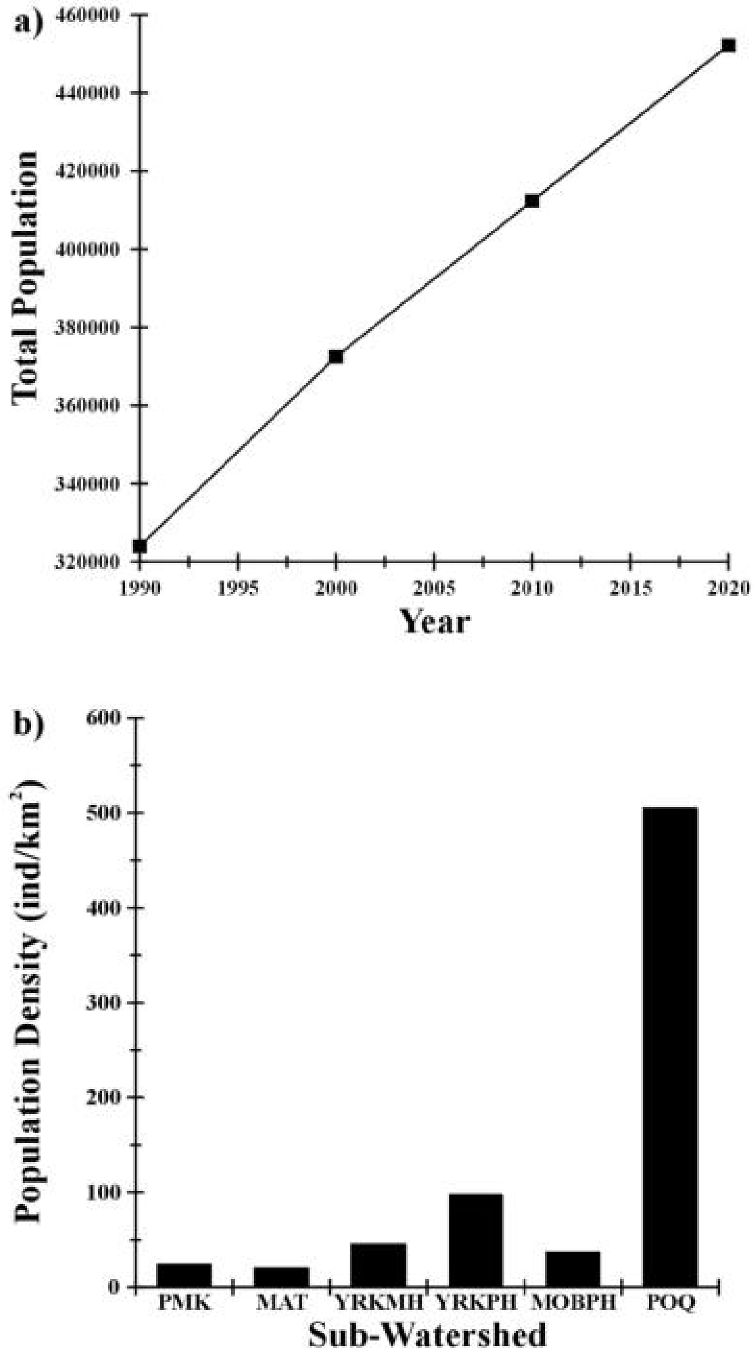


Figure 3-1. Patterns in a) total and projected total watershed population over time and b) population density between sub-watersheds within the York River basin.

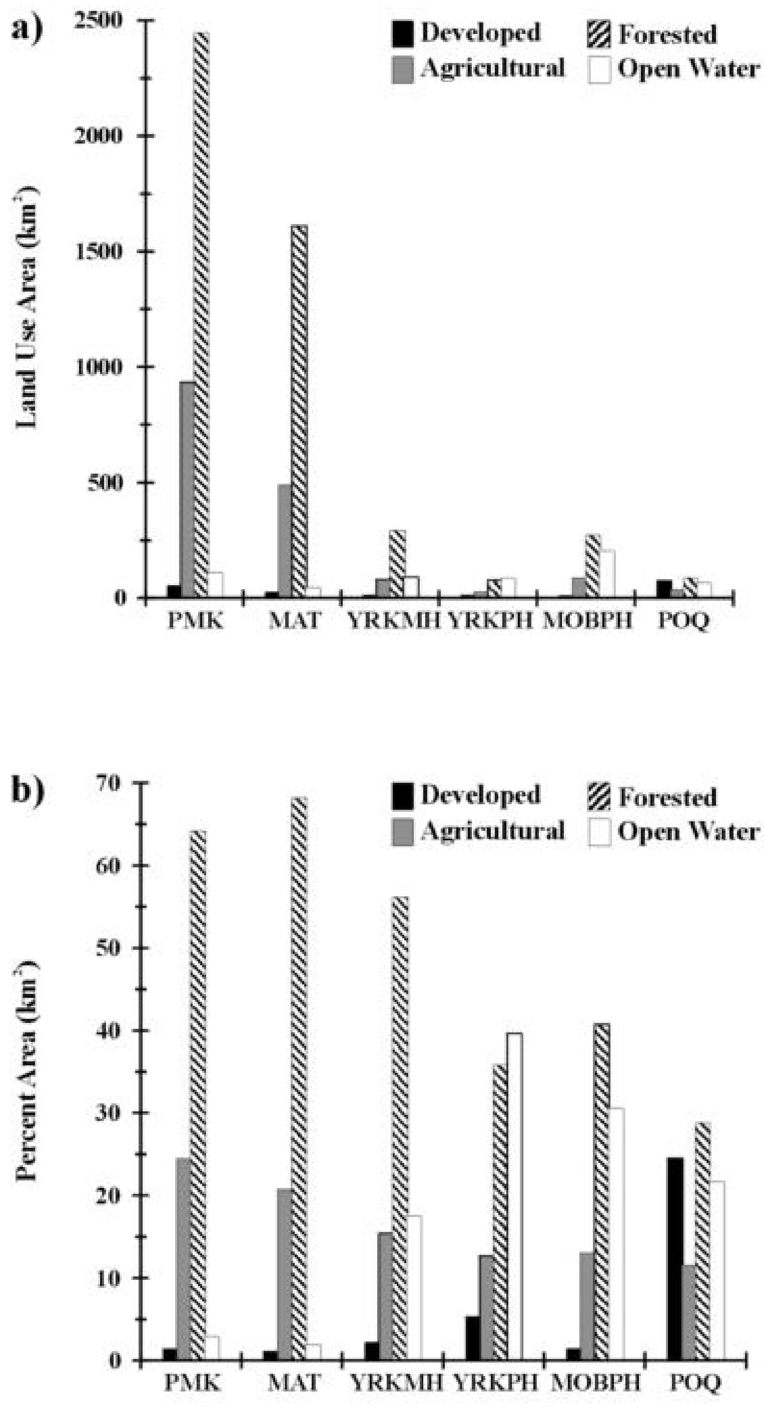


Figure 3-2. Differences in a) total area and b) percentages of land-use types between sub-watersheds of the York River for 1999. Data presented were provided by the USEPA, Chesapeake Bay Program Office.

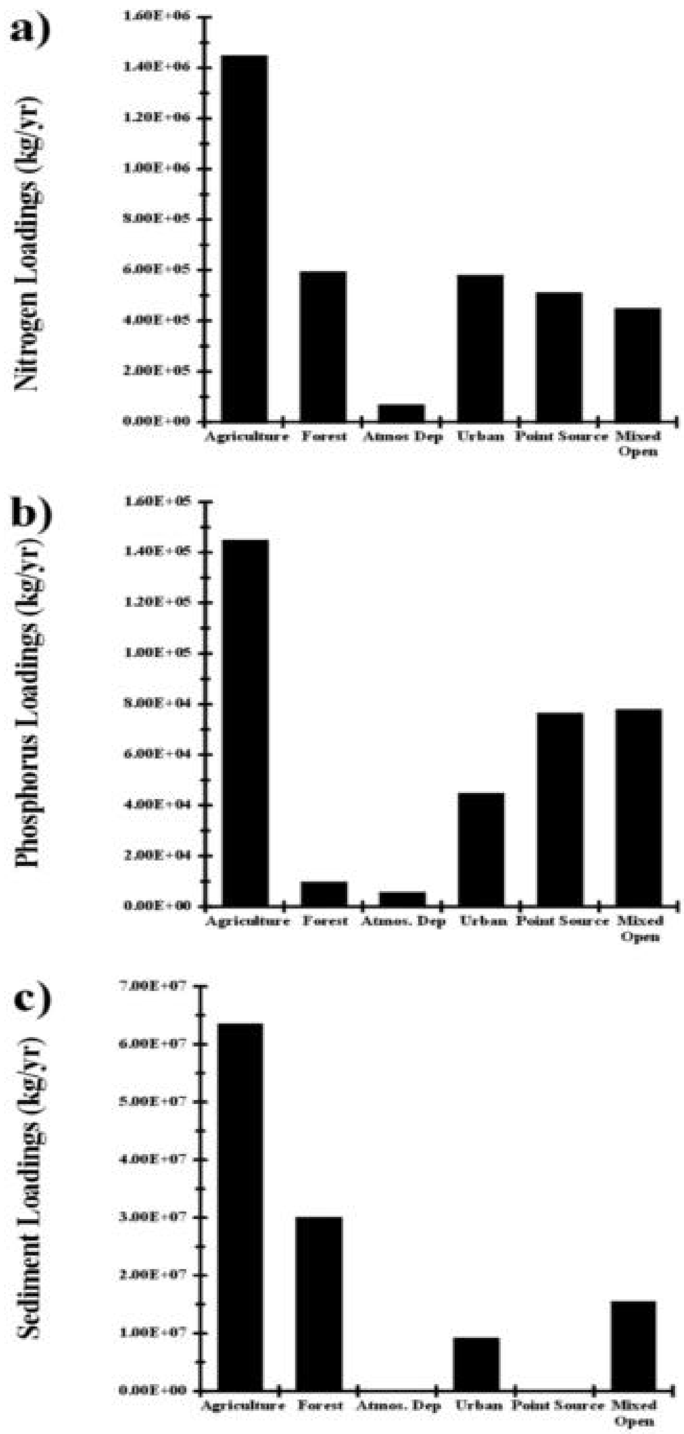


Figure 3-3. Non-point source loadings of a) total nitrogen, b) total phosphorus, and c) sediments by source for the York River in 2000. Data generated using the USEPA Chesapeake Bay Watershed Model.

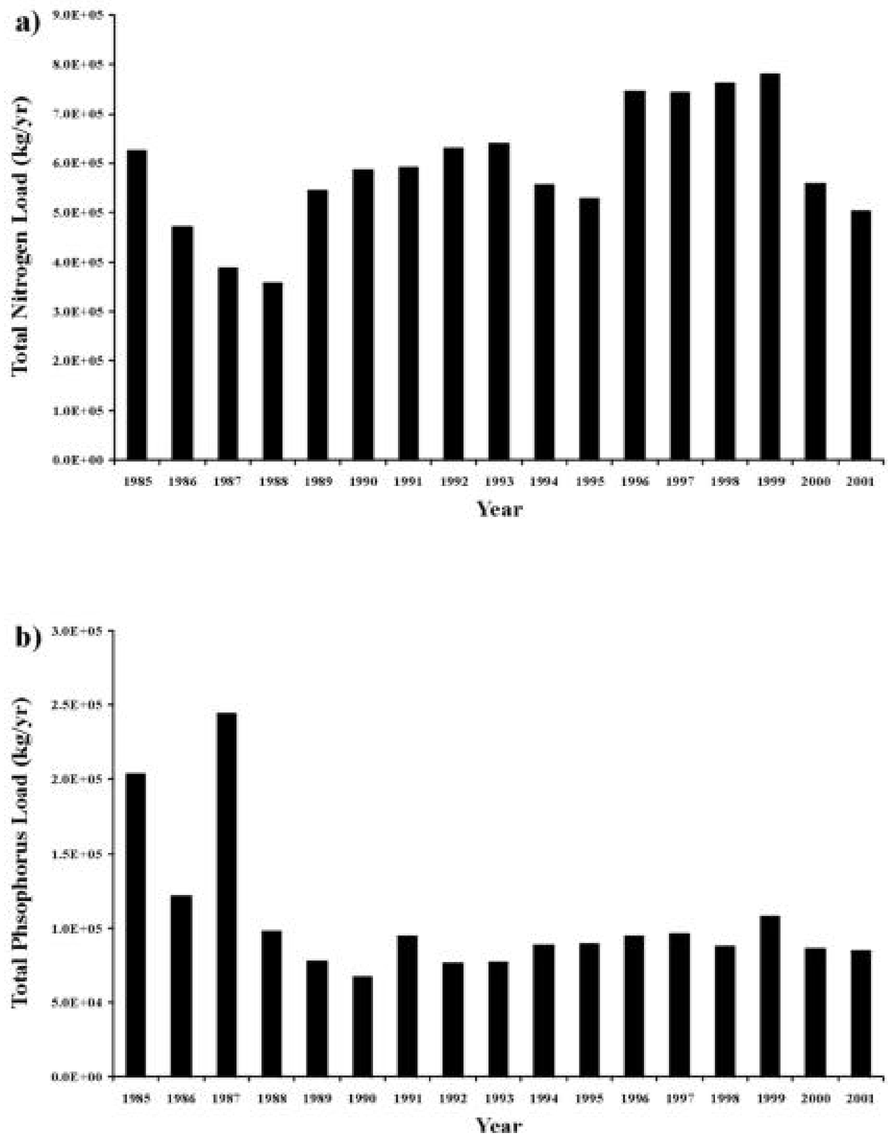
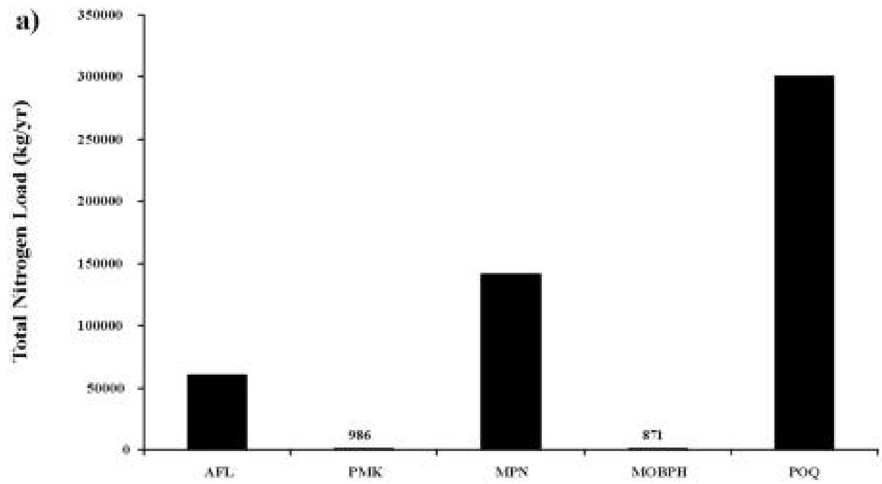


Figure 3-4. Long-term trends in point source a) total nitrogen loadings and b) total phosphorus loadings in the York River from 1985 to 2001.



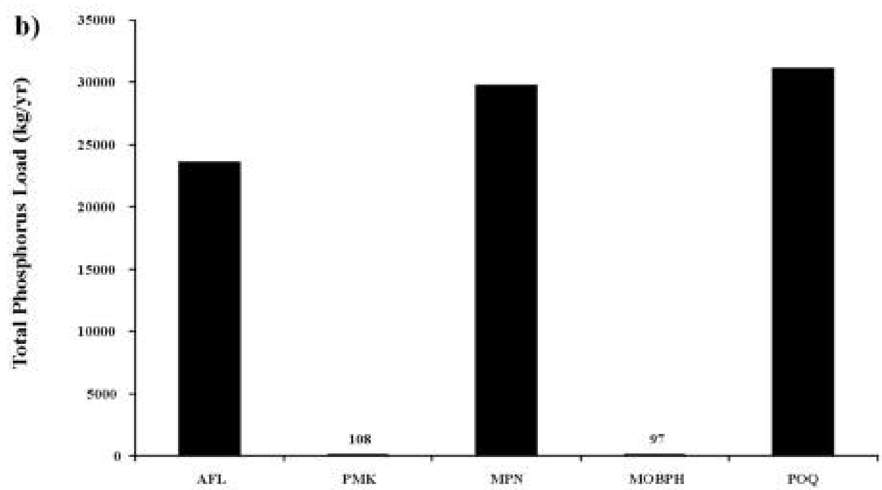


Figure 3-5. Spatial patterns in point source a) total nitrogen and b) total phosphorus loadings in the York River for 2001. AFL=Above the Fall-line (Pamunkey River), PMK=Pamunkey (PMKOH only), MPN=Mattaponi (MPNTF and MPNOH), MOBPH=Mobjack Bay and , POQ=Poquoson Bay sub-watersheds.

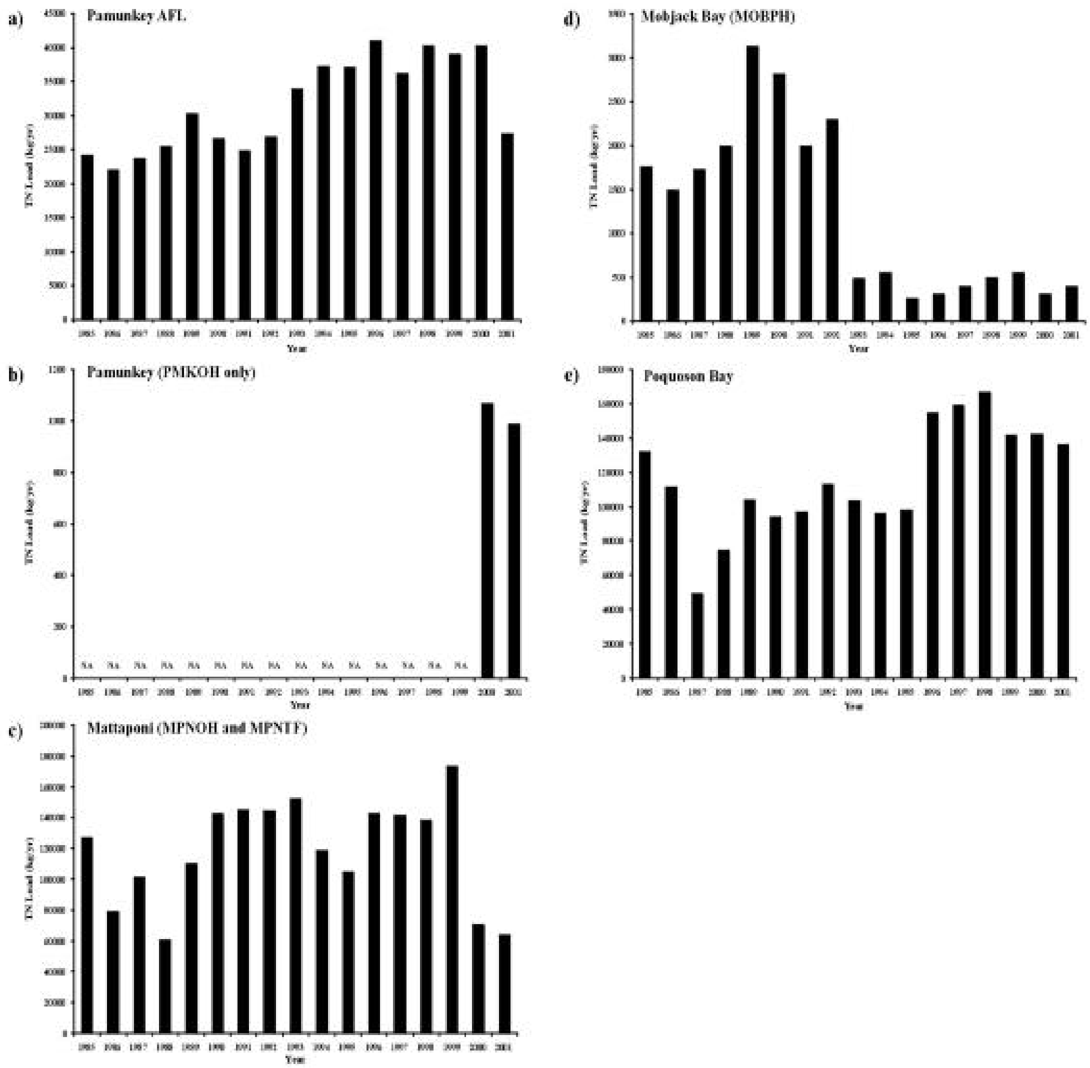


Figure 3-6 Change in point source total nitrogen in the a) Pamunkey River (AFL=Above the Fall-line), b) Pa (PMKOH only), c) Mattaponi River (MPNOH and MPNTF), d) Mobjack Bay (MOBPH), and e) P sub-watersheds of the York River from 1985 to 2001.

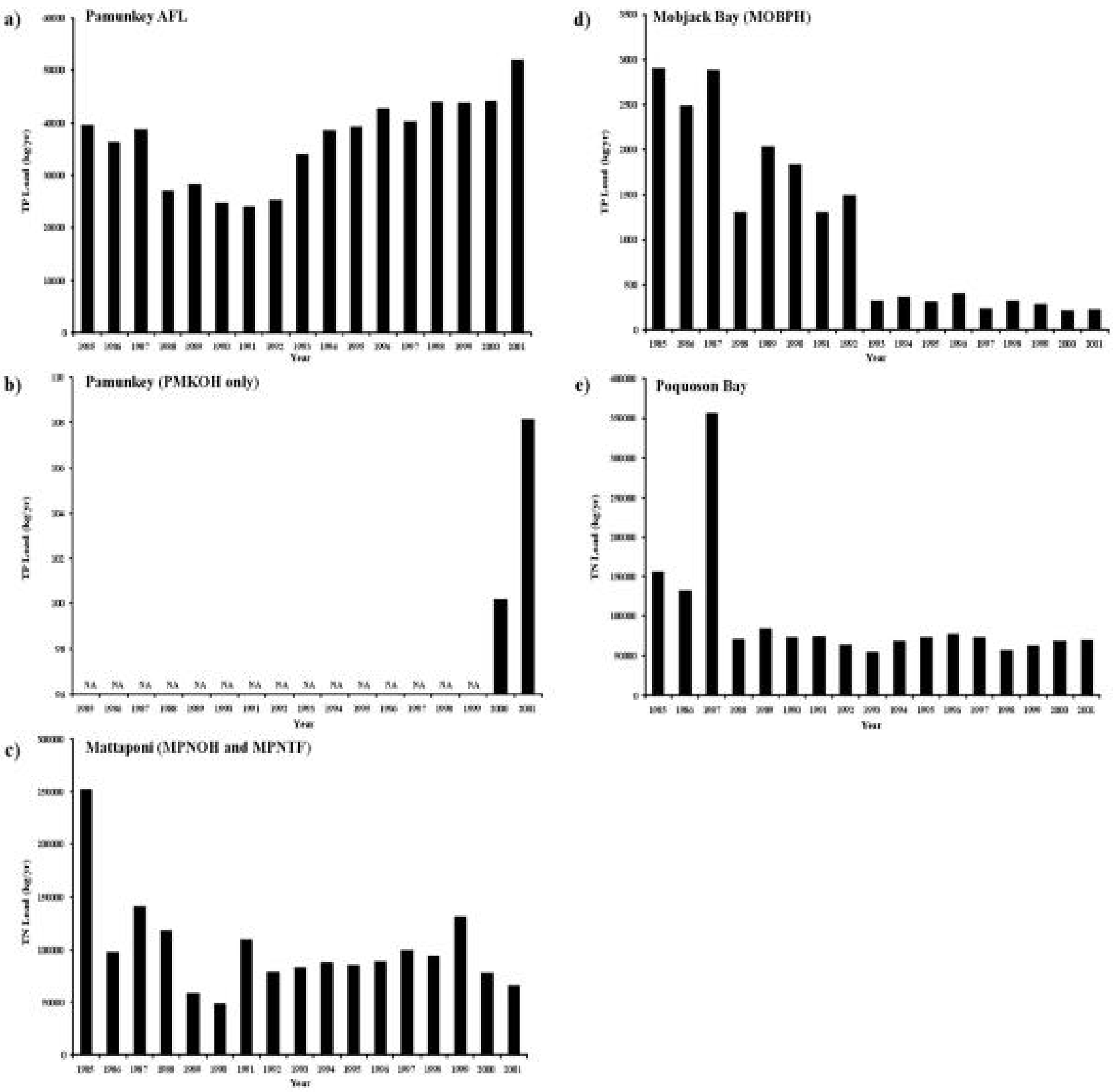


Figure 3-7. Change in point source total phosphorus in the a) Pamunkey River (AFL=Above the Fall-line), b) Pamunkey River (PMKOH only), c) Mattaponi River (MPNOH and MPNTF), d) Mobjack Bay (MOBPH), and e) Poquoson Bay sub-watersheds of the York River from 1985 to 2001.

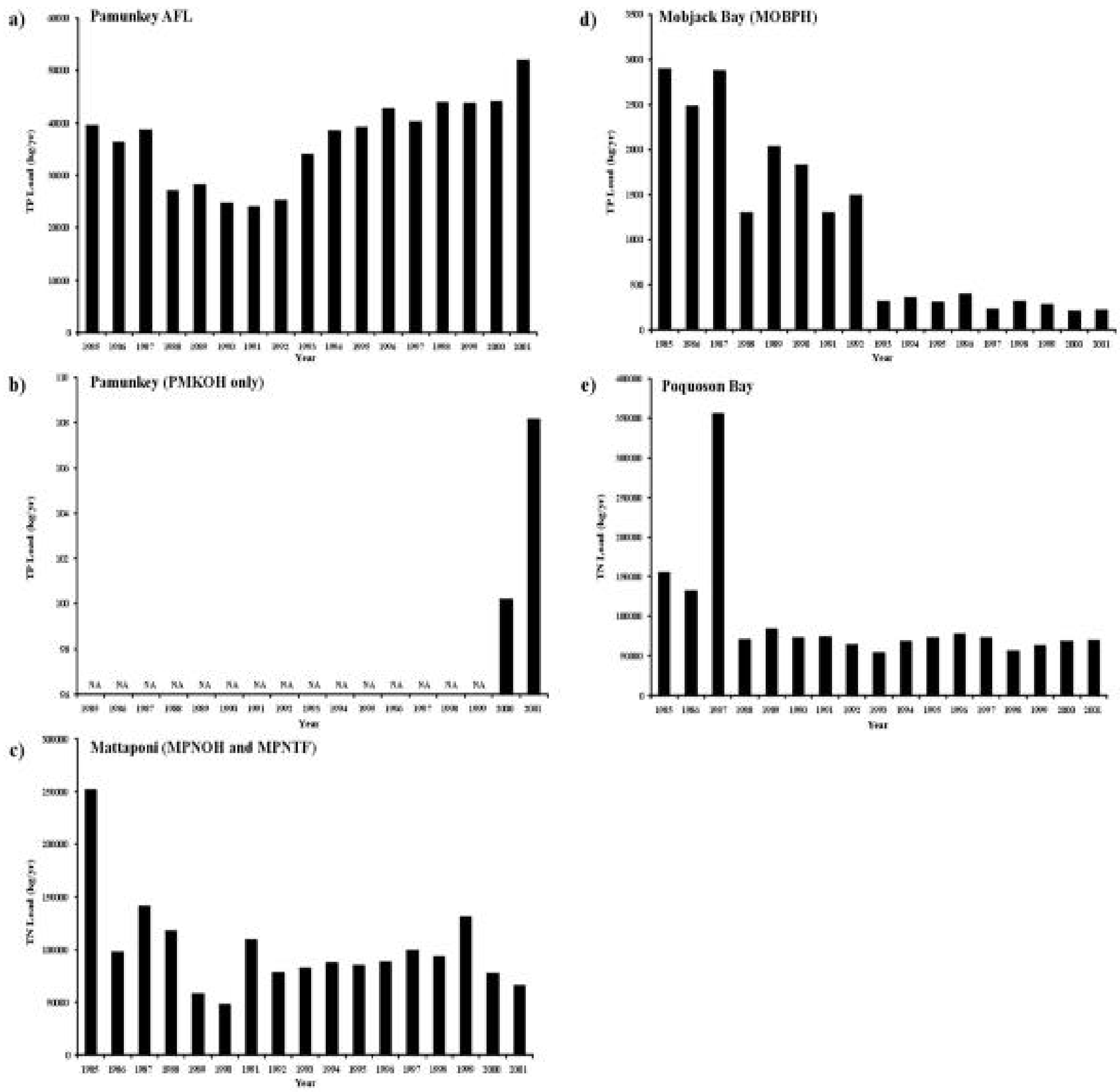


Figure 3-7. Change in point source total phosphorus in the a) Pamunkey River (AFL=Above the Fall-line), b) Pamunkey River (PMKOH only), c) Mattaponi River (MPNOH and MPNTF), d) Mobjack Bay (MOBPH), and e) Poquoson Bay sub-watersheds of the York River from 1985 to 2001.

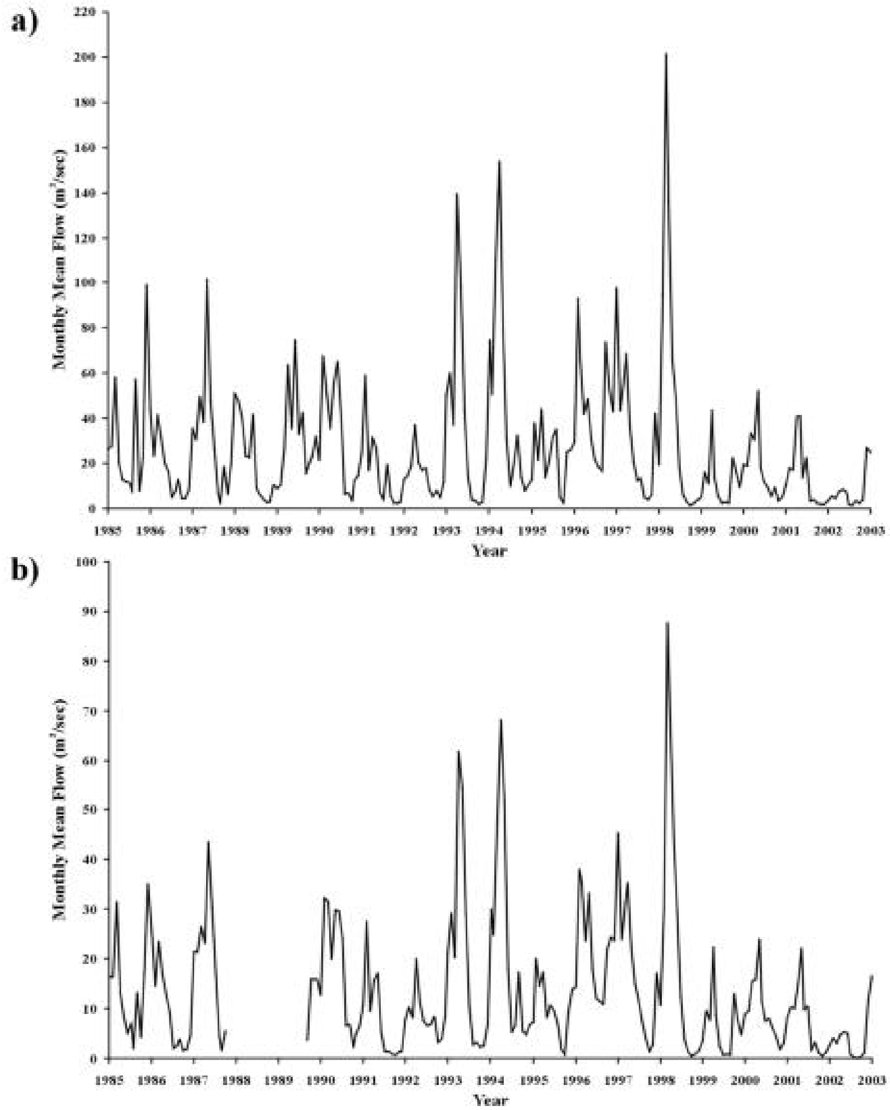


Figure 3-8. Plot of monthly mean flow at the a) Pamunkey River fall-line and b) the Mattaponi River fall-line for the period of 1985 to 2002.

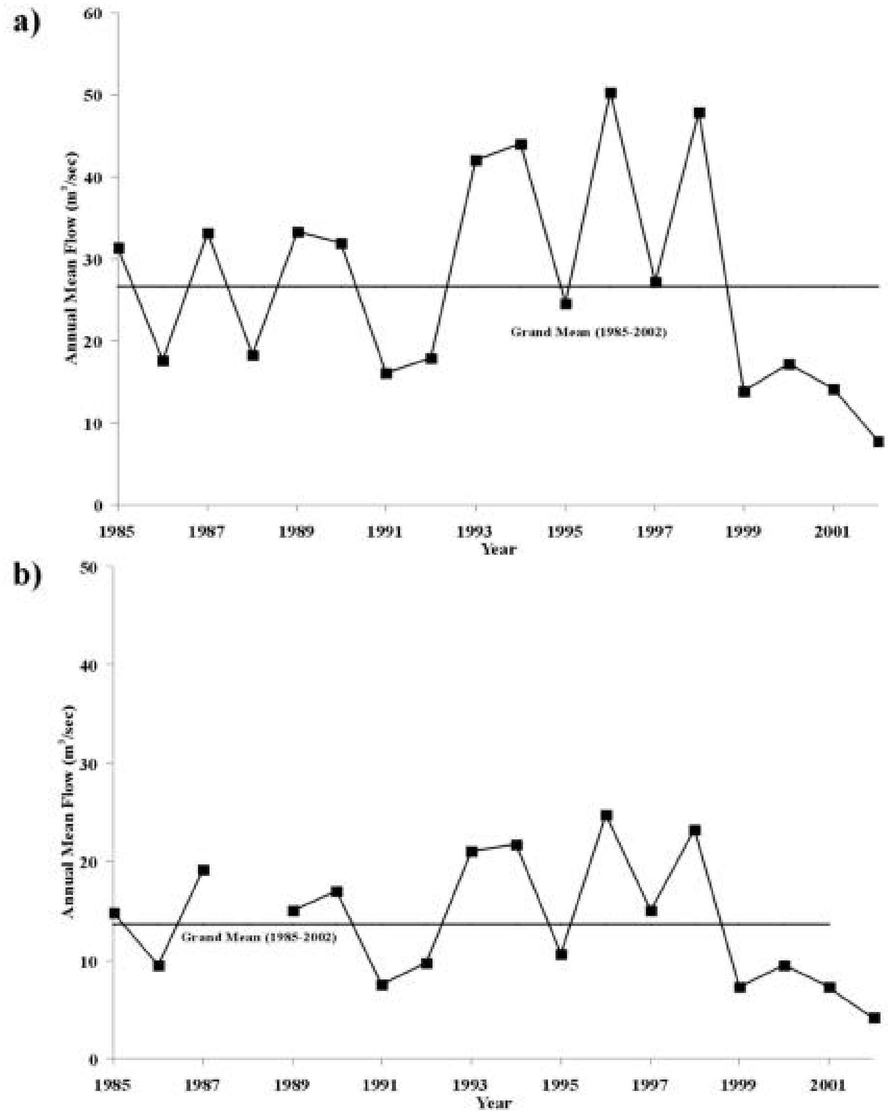


Figure 3-9. Plot of annual mean flow at the a) Pamunkey River fall-line and b) the Mattaponi River fall-line for the period of 1985 to 2002.

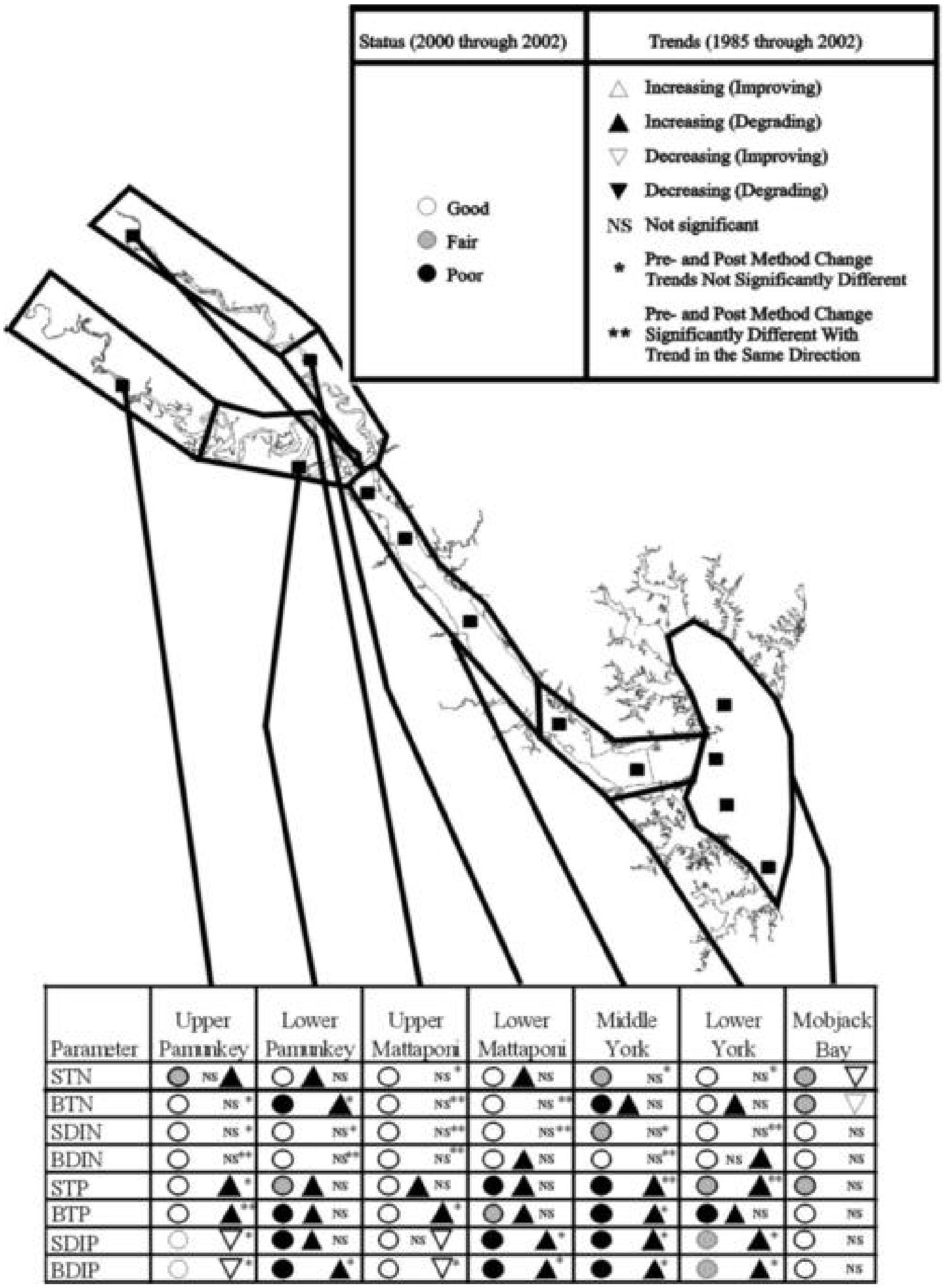
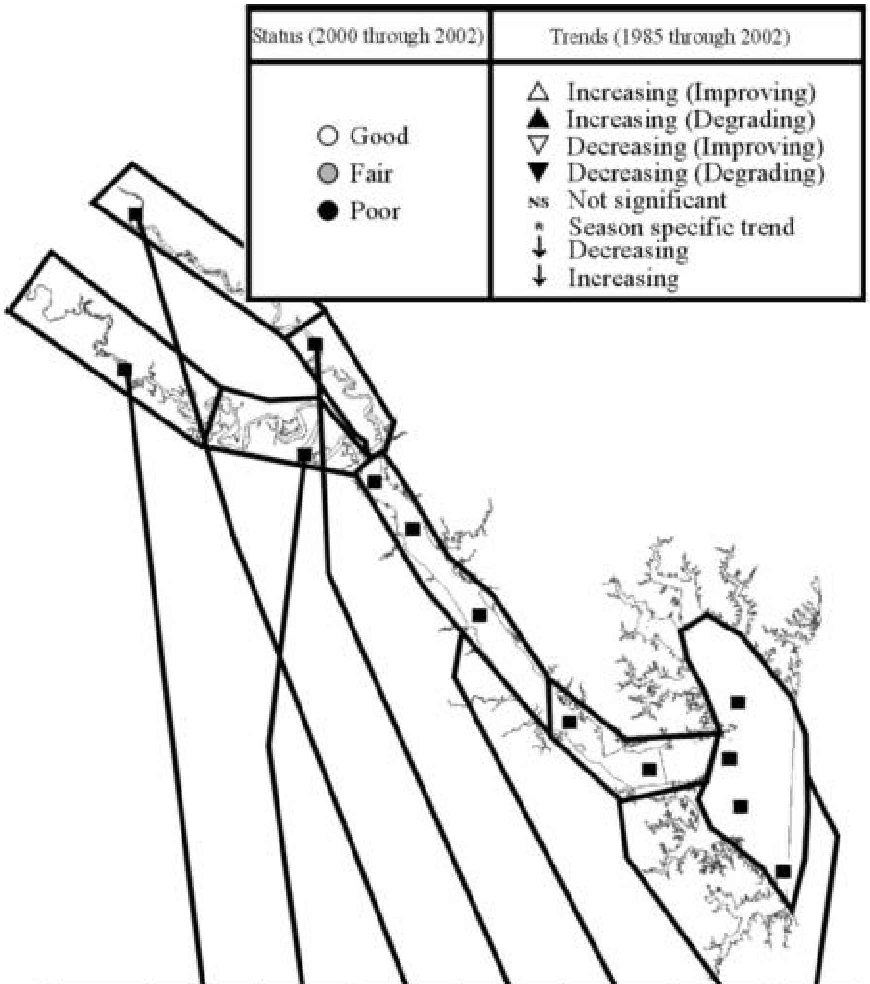
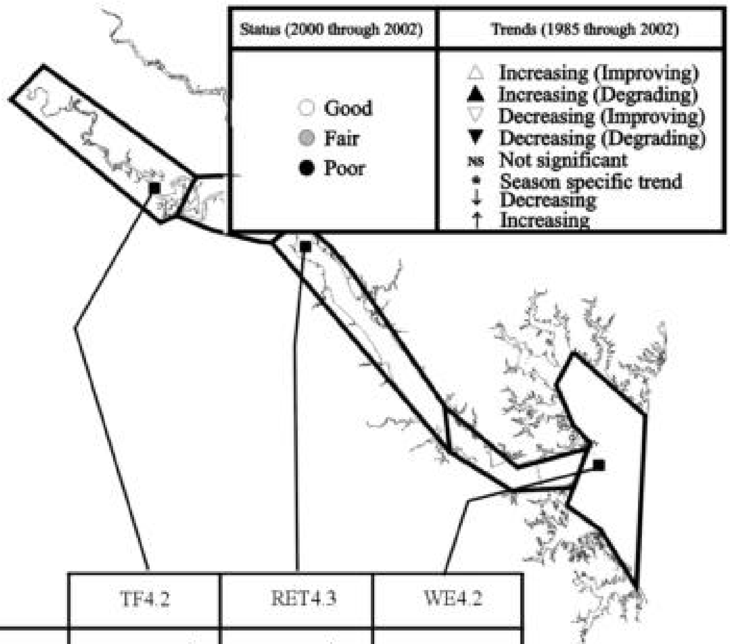


Figure 3-10. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period of 1985 to 2002. Abbreviations for each parameter are: TN=total nitrogen, DIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.



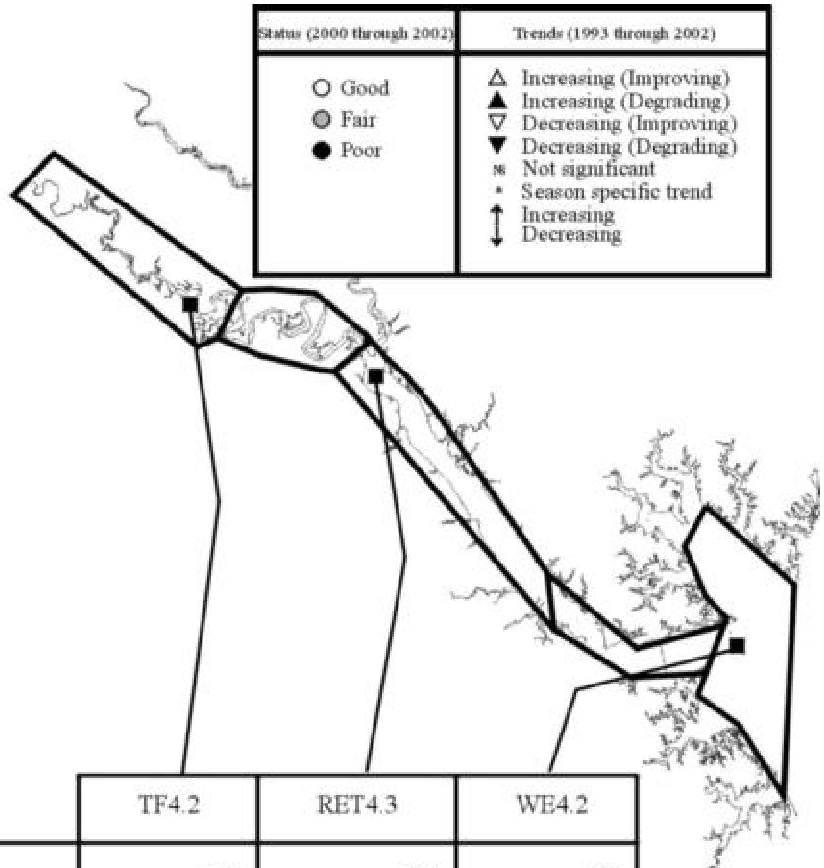
Parameter	Upper Pamunkey		Lower Pamunkey		Upper Mattaponi		Lower Mattaponi		Middle York		Lower York		Mobjack Bay	
SCHLA	○	NS	◍	▲	○	NS	◍	▲	●	▲	●	NS	○	▽
STSS	●	▲	●	NS	○	▲	◍	NS	●	NS	◍	NS	◍	▽
BTSS	◍	NS	●	NS	○	NS	●	NS	●	▲	●	▲	○	▽
SECCHI	◍	NS	◍	△	◍	▼	◍	NS	●	NS	●	▼	●	NS
BDO	○	NS	◍	NS	○	NS	◍	NS	○	△	◍	NS	○	△
SWTEMP		↑		NS		↑		↑		NS		NS		NS
BWTEMP		↑		NS		↑		NS		NS		NS		NS
SSALIN		↑		↑		↑		↑		↑		NS		↑
BSALIN		↑		↑		↑		↑		NS		NS		NS

Figure 3-11. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period of 1985 to 2002. Abbreviations for each parameter are: CHLA=chlorophyll a, TSS=total suspended solids, SECCHI=secchi depth, DO=dissolved oxygen, WTEMP=water temperature, SALIN=salinity. The prefixes S and B refer to surface and bottom measurements, respectively.



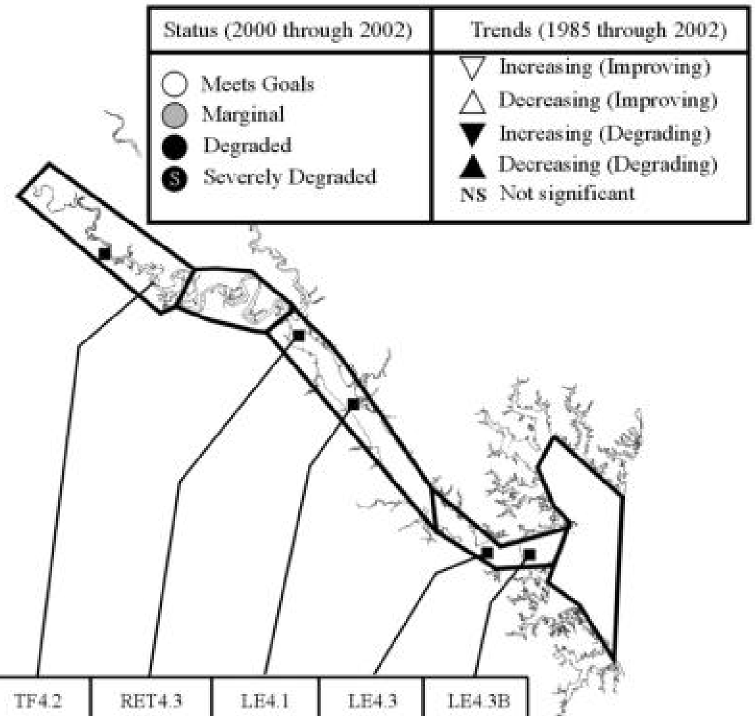
	TF4.2		RET4.3		WE4.2	
Total Abundance		↑		↑		NS
Total Biomass	Poor	↑	Poor	↑	Poor	NS
Biomass to Abundance	Poor	NS	Poor	△	Poor	NS
Margalef Diversity Index	Poor	NS	Fair	NS	Fair	NS
Productivity	Good	NS	Good	NS	Fair	▽
Diatom Biomass	Poor	△	Good	△	Fair	△
Dinoflagellate Biomass	Poor	NS	Poor	NS	Fair	NS
Cyanophyte Biomass	Fair	▲	Poor	▲	Poor	▲
Chlorophyte Biomass	Fair	△	Good	△	Good	△
Picoplankton Biomass	Poor	NS	Poor	▽	Poor	NS
Cryptophyte Biomass		△		△		▼
Procaryote to Eucaryote Biomass	Good	NS	Good	NS	Good	NS
Cyanophyte Abundance	Fair	▲	Poor	▲	Poor	▲

Figure 3-12. Map of the York River basin showing summaries of the status and trend analyses for phytoplankton bioindicators for each segment for the period of 1985 to 2002.



	TF4.2	RET4.3	WE4.2
Total Abundance	NS	NS	NS
Total Biomass	NS	NS	NS
Copepod Nauplii Abundance	◍ NS	○ ▼	● NS
Rotifer Abundance	○ NS	● NS	● ▲
Oligotrich Abundance	NS	NS	NS
Cladoceran Abundance	↓	↓	NS
Tintinnid Abundance	NS	↓	↓
Polychaeta Larvae Abundance	NS	NS	↓

Figure 3-13. Map of the York River basin showing summaries of the status and trend analyses for microzooplankton bioindicators for each segment for the period of 1985 to 2002.



	TF4.2	RET4.3	LE4.1	LE4.3	LE4.3B
Benthic IBI	○ NS	◍ ▼	◍ NS	○ NS	○ △
Total Abundance	△	NS	NS	NS	NS
Total Biomass	NS	NS	NS	NS	NS
Pollution Sensitive Species Abundance (%)	NS	NS	NS	NS	△
Pollution Indicative Species Abundance (%)	NS	NS	NS	NS	▽
Pollution Sensitive Species Biomass (%)	NS	NS	▼	NS	NS
Pollution Indicative Species Biomass (%)	NS	NS	NS	NS	NS
Shannon-Weiner Diversity Index	△	NS	▼	NS	△

Figure 3-14. Map of the York River basin showing summaries of the status and trend analyses for benthic bioindicators for each segment for the period of 1985 to 2002.

Table 3-1. Water quality trends at York RIM stations 1674500 (Mattaponi River near Beulahville), 1673000 (Pamunkey River at Hanover), and 1671020 (North Anna River at Doswell).

River	Station	Parameter	DataType	Status	Slope	pValue	Direction
Pamunkey River at Hanover	1673000	FLOW	FLOW	411.95000	-0.0446	0.0259	**Decreasing**
Pamunkey River at Hanover	1673000	TN	FAC	-	0.0118	0.0008	**Degrading**
Pamunkey River at Hanover	1673000	TN	FWC	1.69300	0.0114	0.0001	**Degrading**
Pamunkey River at Hanover	1673000	NO23F	FAC	-	0.0186	0.0002	**Degrading**
Pamunkey River at Hanover	1673000	NO23F	FWC	0.66856	0.0259	0.0001	**Degrading**
Pamunkey River at Hanover	1673000	TP	FAC	-	0.0335	0.0000	**Degrading**
Pamunkey River at Hanover	1673000	TP	FWC	0.24365	0.0343	0.0001	**Degrading**
Pamunkey River at Hanover	1673000	PO4F	FAC	-	0.0662	0.0000	**Degrading**
Pamunkey River at Hanover	1673000	PO4F	FWC	0.08181	0.0802	0.0001	**Degrading**
Pamunkey River at Hanover	1673000	PO4F	LOAD	0.04245	0.0356	0.0134	**Degrading**
Pamunkey River at Hanover	1673000	TSS	FAC	-	0.0342	0.0027	**Degrading**
Mattaponi River at Beulahville	1674500	FLOW	FLOW	280.40000	-0.0415	0.0423	**Improving**
Mattaponi River at Beulahville	1674500	TN	FAC	-	-0.0104	0.0007	**Improving**
Mattaponi River at Beulahville	1674500	TN	FWC	1.20481	-0.0096	0.0019	**Improving**
Mattaponi River at Beulahville	1674500	TN	LOAD	0.79420	-0.0511	0.0229	**Improving**
Mattaponi River at Beulahville	1674500	NO23F	FAC	-	-0.0238	0.0006	**Improving**
Mattaponi River at Beulahville	1674500	NO23F	FWC	0.33318	-0.0155	0.0001	**Improving**
Mattaponi River at Beulahville	1674500	NO23F	LOAD	0.19853	-0.0570	0.0025	**Improving**
Mattaponi River at Beulahville	1674500	TP	FAC	-	-0.0097	0.0428	**Improving**
Mattaponi River at Beulahville	1674500	TP	FWC	0.11819	-0.0131	0.0010	**Improving**
Mattaponi River at Beulahville	1674500	TP	LOAD	0.07509	-0.0546	0.0186	**Improving**
Mattaponi River at Beulahville	1674500	PO4F	LOAD	0.01785	-0.0424	0.0428	**Improving**
Mattaponi River at Beulahville	1674500	TSS	FWC	17.05876	-0.0304	0.0324	**Improving**
Mattaponi River at Beulahville	1674500	TSS	LOAD	11.19490	-0.0718	0.0336	**Improving**
North Anna River at Doswell	1671020	FLOW	FLOW	112.85000	-0.0236	0.0413	**Decreasing**
North Anna River at Doswell	1671020	TNH4	FAC	-	-0.0134	0.0000	**Improving**
North Anna River at Doswell	1671020	TNH4	FWC	0.03651	-0.0136	0.0001	**Improving**
North Anna River at Doswell	1671020	TNH4	LOAD	0.03091	-0.0372	0.0022	**Improving**
North Anna River at Doswell	1671020	TKN	FAC	-	0.0124	0.0097	**Degrading**
North Anna River at Doswell	1671020	TKN	FWC	0.27016	0.0082	0.0001	**Degrading**
North Anna River at Doswell	1671020	NO23W	FWC	0.10002	-0.0144	0.0006	**Improving**
North Anna River at Doswell	1671020	NO23W	LOAD	0.08126	-0.0380	0.0126	**Improving**
North Anna River at Doswell	1671020	NO3W	FWC	0.09393	-0.0128	0.0045	**Improving**
North Anna River at Doswell	1671020	NO3W	LOAD	0.07602	-0.0364	0.0184	**Improving**
North Anna River at Doswell	1671020	TP	FAC	-	-0.1083	0.0000	**Improving**
North Anna River at Doswell	1671020	TP	FWC	0.01588	-0.1109	0.0001	**Improving**
North Anna River at Doswell	1671020	TP	LOAD	0.01355	-0.1345	0.0001	**Improving**
North Anna River at Doswell	1671020	TSS	FAC	-	0.0283	0.0012	**Degrading**

Table 3-2. Water quality status in segment MOBPH (value is the median concentration, secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	SValue	SScore	SStatus	BValue	BScore	BStatus
MOBPH	TN	Annual	0.4093	42.6	**Fair**	0.3978	44.6	**Fair**
MOBPH	TN	Spring1	0.3754	31.4	**Good**	0.3495	38.5	**Good**
MOBPH	TN	Spring2	0.4311	51.1	**Fair**	0.411	63	**Poor**
MOBPH	TN	Summer1	0.4906	64.2	**Poor**	0.4944	62.3	**Poor**
MOBPH	TN	Summer2	0.4915	63.4	**Poor**	0.495	59.8	**Poor**
MOBPH	DIN	Annual	0.0106	14.1	**Good**	0.0134	8.8	**Good**
MOBPH	DIN	Spring1	0.0063	6.4	**Good**	0.0079	8.2	**Good**
MOBPH	DIN	Spring2	0.0064	14.5	**Good**	0.0084	8.9	**Good**
MOBPH	DIN	Summer1	0.0127	30.6	**Good**	0.0288	17.9	**Good**
MOBPH	DIN	Summer2	0.0139	28.7	**Good**	0.032	14.7	**Good**
MOBPH	TP	Annual	0.0268	56.2	**Fair**	0.0268	32	**Good**
MOBPH	TP	Spring1	0.0196	48.4	**Fair**	0.0235	19.8	**Good**
MOBPH	TP	Spring2	0.0281	71.5	**Poor**	0.0318	60.4	**Poor**
MOBPH	TP	Summer1	0.0405	82.2	**Poor**	0.046	45.7	**Good**
MOBPH	TP	Summer2	0.0441	79.7	**Poor**	0.0491	37.6	**Good**
MOBPH	PO4F	Annual	0.0021	22.6	**Good**	0.0025	18.1	**Good**
MOBPH	PO4F	Spring1	0.0007	2.1	**Good**	0.0006	1	**Good**
MOBPH	PO4F	Spring2	0.0008	6.1	**Good**	0.0014	8.2	**Good**
MOBPH	PO4F	Summer1	0.0053	51.4	**Fair**	0.0084	29.2	**Good**
MOBPH	PO4F	Summer2	0.0065	59.8	**Poor**	0.0088	24.9	**Good**
MOBPH	CHLA	Annual	4.9529	38.9	**Good**	-	-	-
MOBPH	CHLA	Spring1	3.4710	18.2	**Good**	-	-	-
MOBPH	CHLA	Spring2	5.0330	39.2	**Good**	-	-	-
MOBPH	CHLA	Summer1	9.6549	74.5	**Poor**	-	-	-
MOBPH	CHLA	Summer2	9.9992	72.6	**Poor**	-	-	-
MOBPH	TSS	Annual	8.9925	49.6	**Fair**	12.6649	28.1	**Good**
MOBPH	TSS	Spring1	7.3900	42.4	**Fair**	11.74	16.1	**Good**
MOBPH	TSS	Spring2	9.7000	64.2	**Poor**	12.8482	54.6	**Fair**
MOBPH	TSS	Summer1	12.5800	67.7	**Poor**	20.2513	53.8	**Fair**
MOBPH	TSS	Summer2	12.9350	67.6	**Poor**	21.731	54.8	**Fair**
MOBPH	SECCHI	Annual	1.3250	19.8	**Poor**	-	-	-
MOBPH	SECCHI	Spring1	1.3500	24.6	**Poor**	-	-	-
MOBPH	SECCHI	Spring2	1.2500	9.6	**Poor**	-	-	-
MOBPH	SECCHI	Summer1	1.1417	10.6	**Poor**	-	-	-
MOBPH	SECCHI	Summer2	1.1250	12.9	**Poor**	-	-	-
MOBPH	DO	Spring1	-	-	-	9.3	.	**Meets**
MOBPH	DO	Spring2	-	-	-	8.795	.	**Meets**
MOBPH	DO	Summer1	-	-	-	6.8073	.	**Meets**
MOBPH	DO	Summer2	-	-	-	6.7075	.	**Meets**

Table 3-3. Water quality trends in segment MOBPH (only significant trends are displayed).

Segment	Parameter	Layer	Season	Baseline	Slope	% Change	% BDL	pValue	Direction
MOBPH	TN	S	Annual	0.489	-0.0075	-24.40	0.00	0.0000	**Improving**
MOBPH	TN	B	Annual	0.495	-0.0079	-25.44	0.00	0.0000	**Improving**
MOBPH	DIN	S	Annual	0.035	0.0000	0.00	0.96	0.0000	**Improving**
MOBPH	DIN	B	Annual	0.044	0.0000	-1.35	0.67	0.0001	**Improving**
MOBPH	PO4F	S	Annual	0.005	0.0000	0.00	0.00	0.0004	**Improving**
MOBPH	PO4F	B	Annual	0.005	0.0000	0.00	0.00	0.0007	**Improving**
MOBPH	CHLA	S	Annual	7.03	-0.1131	-25.76	0.00	0.0258	**Improving**
MOBPH	CHLA	B	Annual	6.95	-0.0941	-21.66	0.00	0.0305	**Improving**
MOBPH	TSS	S	Annual	11.00	-0.3500	-50.91	2.40	0.0001	**Improving**
MOBPH	TSS	B	Annual	17.25	-0.2875	-26.67	0.86	0.0074	**Improving**
MOBPH	DO	B	Summer1	5.33	0.0800	24.04	0.00	0.0000	**Improving**
MOBPH	SALINITY	S	Annual	20.93	0.0565	4.32	0.00	0.0422	**Increasing**

Table 3-4. SAV season water quality status in segment MOBPH (value is the median concentration; secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Value	Score	Status	Habitat Requirement
MOBPH	DIN	SAV2	0.0092	5.4	**Good**	**Meets**
MOBPH	PO4F	SAV2	0.0029	23.7	**Good**	**Meets**
MOBPH	CHLA	SAV2	4.6191	40	**Good**	**Meets**
MOBPH	TSS	SAV2	7.9963	49.1	**Fair**	**Meets**
MOBPH	SECCHI	SAV2	1.35	14	**Poor**	**Meets**

Table 3-5. SAV Season Water quality trends in segment MOBPH (only significant trends are displayed).

Segment	Layer	Season	Parameter	Baseline	Slope	% Change	p Value	% BDL	Direction
MOBPH	S	SAV2	STN	0.491	-0.009	-29.44	0.0000	0.00	**Improving**
MOBPH	S	SAV2	SDIN	0.042	-0.001	-42.93	0.0000	1.19	**Improving**
MOBPH	S	SAV2	SPO4F	0.005	0.000	0.00	0.0145	0.00	**Improving**
MOBPH	S	SAV2	SCHLA	5.51	-0.10	-28.48	0.0145	0.00	**Improving**
MOBPH	S	SAV2	STSS	12.00	-0.29	-38.69	0.0018	2.58	**Improving**

Table 3-6. Water quality status in segment YRKPH (value is the medi an concentration, secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Svalue	Sscore	Sstatus	Bvalue	Bscore	Bstatus
YRKPH	TN	ANNUAL	0.4480	18.1	Good	0.5125	39.0	Good
YRKPH	TN	SPRING1	0.4270	15.9	Good	0.5020	42.1	Good
YRKPH	TN	SPRING2	0.4405	23.7	Good	0.5250	50.1	Fair
YRKPH	TN	SUMMER1	0.4840	25.5	Good	0.5415	38.8	Good
YRKPH	TN	SUMMER2	0.4880	22.4	Good	0.5510	36.2	Good
YRKPH	DIN	ANNUAL	0.0298	4.2	Good	0.0478	12.6	Good
YRKPH	DIN	SPRING1	0.0210	2.7	Good	0.0270	8.4	Good
YRKPH	DIN	SPRING2	0.0228	4.9	Good	0.0295	9.4	Good
YRKPH	DIN	SUMMER1	0.0498	24.2	Good	0.1206	27.2	Good
YRKPH	DIN	SUMMER2	0.0555	29.4	Good	0.1520	35.2	Good
YRKPH	TP	ANNUAL	0.0595	47.9	Fair	0.0789	74.4	Poor
YRKPH	TP	SPRING1	0.0419	30.7	Good	0.0643	48.1	Fair
YRKPH	TP	SPRING2	0.0474	43.2	Fair	0.0809	75.9	Poor
YRKPH	TP	SUMMER1	0.0795	57.1	Fair	0.0945	79.0	Poor
YRKPH	TP	SUMMER2	0.0800	46.1	Fair	0.0920	66.1	Poor
YRKPH	PO4F	ANNUAL	0.0173	49.3	Fair	0.0188	48.0	Fair
YRKPH	PO4F	SPRING1	0.0090	56.6	Fair	0.0100	48.1	Fair
YRKPH	PO4F	SPRING2	0.0109	37.5	Good	0.0125	37.1	Good
YRKPH	PO4F	SUMMER1	0.0244	43.9	Fair	0.0305	52.8	Fair
YRKPH	PO4F	SUMMER2	0.0415	56.3	Fair	0.0405	64.8	Poor
YRKPH	CHLA	ANNUAL	8.8400	59.0	Poor	-	-	-
YRKPH	CHLA	SPRING1	8.9500	27.9	Good	-	-	-
YRKPH	CHLA	SPRING2	10.6600	50.0	Fair	-	-	-
YRKPH	CHLA	SUMMER1	10.1350	73.3	Poor	-	-	-
YRKPH	CHLA	SUMMER2	9.9300	77.3	Poor	-	-	-
YRKPH	TSS	ANNUAL	10.5000	49.6	Fair	26.0000	73.3	Poor
YRKPH	TSS	SPRING1	16.1250	46.2	Fair	23.0000	63.7	Poor
YRKPH	TSS	SPRING2	16.1250	53.7	Fair	35.5000	64.6	Poor
YRKPH	TSS	SUMMER1	9.2500	36.5	Good	24.7500	51.3	Fair
YRKPH	TSS	SUMMER2	8.5000	23.8	Good	20.0000	20.9	Good
YRKPH	SECCHI	ANNUAL	1.1500	37.2	Poor	-	-	-
YRKPH	SECCHI	SPRING1	1.0000	42.2	Poor	-	-	-
YRKPH	SECCHI	SPRING2	0.8500	28.9	Poor	-	-	-
YRKPH	SECCHI	SUMMER1	0.9500	28.2	Poor	-	-	-
YRKPH	SECCHI	SUMMER2	0.9500	21.1	Poor	-	-	-
YRKPH	DO	SPRING1	-	-	-	8.5300	.	Good
YRKPH	DO	SPRING2	-	-	-	7.0750	.	Good
YRKPH	DO	SUMMER1	-	-	-	4.7625	.	Fair
YRKPH	DO	SUMMER2	-	-	-	4.1550	.	Fair

Table 3-7. Water quality trends in segment YRKPH (only significant trends are displayed).

a) Nutrient parameters

Segment	Layer	Parameter	'93 Trend p value	'93 Slope	'02 Trend p value	'02 Slope	Trend Comparison p value	Trend Comparison	Combined Trend p value	Combined Trend Direction
YRKPH	S	TN	0.5435	0.0000	0.9662	0.0000	0.5388	No Sign. Dif.	0.4362	NS
YRKPH	B	TN	0.0016	0.0185	0.7622	-0.0014	0.0002	Sign. Dif.	0.0021	-
YRKPH	S	DIN	0.4336	0.0000	0.0866	0.0000	0.0191	Sign. Dif.	0.3153	-
YRKPH	B	DIN	0.0693	0.0000	0.0117	0.0000	0.0001	Sign. Dif.	0.3423	-
YRKPH	S	TP	0.0000	0.0033	0.0023	0.0025	0.0299	Sign. Dif.	0.0000	-
YRKPH	B	TP	0.0000	0.0038	0.0502	0.0033	0.0027	Sign. Dif.	0.0000	-
YRKPH	S	PO4F	0.0005	0.0000	0.0000	0.0010	0.1170	No Sign. Dif.	0.0000	**Degrading**
YRKPH	B	PO4F	0.0050	0.0000	0.0000	0.0011	0.0518	No Sign. Dif.	0.0000	**Degrading**

b) Non-nutrient parameters

Segment	Parameter	Layer	Season	Baseline	Slope	% Change	% BDL	p Value	Direction
YRKPH	TSS	B	Annual	17.75	0.5000	42.25	5.58	0.0326	**Degrading**
YRKPH	SECCHI	S	Annual	1.20	-0.0071	-10.71	0.00	0.0460	**Degrading**

Table 3-8. SAV season water quality status in segment YRKPH (value is the median concentration; secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Value	Score	Status	Habitat Requirement
YRKPH	DIN	SAV2	0.026	2.8	**Good**	**Meets**
YRKPH	PO4F	SAV2	0.0205	55.9	**Fair**	**Fails**
YRKPH	CHLA	SAV2	6.815	44.1	**Fair**	**Meets**
YRKPH	TSS	SAV2	10.5	42.8	**Good**	**Meets**
YRKPH	SECCHI	SAV2	1.15	35.9	**Poor**	**Meets**

Table 3-9. SAV Season Water quality trends in segment YRKPH (only significant trends are displayed).

a) Nutrient parameters

Segment	Layer	Parameter	‘93 Trend p value	‘93 Slope	‘02 Trend p value	‘02 Slope	Trend Comparison p value	Trend Comparison	Combined Trend p value	Combined Trend Direction
YRKPH	S	TN	0.0193	0.0130	0.7713	-0.0011	0.00968	Sign. Dif.	0.04928	-
YRKPH	S	DIN	0.3438	0.0000	0.2210	0.0000	0.68512	No Sign. Dif.	0.04262	**Improving**
YRKPH	S	TP	0.0002	0.0029	0.2476	0.0015	0.00947	Sign. Dif.	0.00000	-
YRKPH	S	PO4F	0.3829	0.0000	0.0007	0.0000	0.02542	Sign. Dif.	0.00004	-

b) Non-nutrient parameters

Segment	Layer	Season	Parameter	Baseline	Slope	% Change	p value	% BDL	Direction
YRKPH	S	SAV2	SECCHI	1.00	-0.01	-18.00	0.0218	0.00	**Degrading**

Table 3-10. Water quality status in segment YRKMH (value is the median concentration, secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Svalue	Sscore	Sstatus	Bvalue	Bscore	Bstatus
YRKMH	TN	ANNUAL	0.6920	49.5	**Fair**	0.8290	76.7	**Poor**
YRKMH	TN	SPRING1	0.7010	52.2	**Fair**	0.8205	67.1	**Poor**
YRKMH	TN	SPRING2	0.7010	64.1	**Poor**	0.8270	80.8	**Poor**
YRKMH	TN	SUMMER1	0.6493	54.0	**Fair**	0.8113	73.6	**Poor**
YRKMH	TN	SUMMER2	0.6540	56.4	**Fair**	0.7430	62.8	**Poor**
YRKMH	DIN	ANNUAL	0.0890	42.5	**Fair**	0.0840	34.4	**Good**
YRKMH	DIN	SPRING1	0.0615	5.0	**Good**	0.0530	6.3	**Good**
YRKMH	DIN	SPRING2	0.0600	17.6	**Good**	0.0530	9.1	**Good**
YRKMH	DIN	SUMMER1	0.0790	57.2	**Fair**	0.0845	45.5	**Fair**
YRKMH	DIN	SUMMER2	0.0810	59.7	**Poor**	0.0850	54.7	**Fair**
YRKMH	TP	ANNUAL	0.0956	89.4	**Poor**	0.1258	92.4	**Poor**
YRKMH	TP	SPRING1	0.0917	84.6	**Poor**	0.1205	87.6	**Poor**
YRKMH	TP	SPRING2	0.0918	87.4	**Poor**	0.1250	89.7	**Poor**
YRKMH	TP	SUMMER1	0.1024	91.2	**Poor**	0.1292	92.5	**Poor**
YRKMH	TP	SUMMER2	0.1060	91.6	**Poor**	0.1284	92.9	**Poor**
YRKMH	PO4F	ANNUAL	0.0210	84.2	**Poor**	0.0230	85.6	**Poor**
YRKMH	PO4F	SPRING1	0.0115	72.6	**Poor**	0.0110	73.6	**Poor**
YRKMH	PO4F	SPRING2	0.0135	75.9	**Poor**	0.0150	76.6	**Poor**
YRKMH	PO4F	SUMMER1	0.0313	87.5	**Poor**	0.0348	89.3	**Poor**
YRKMH	PO4F	SUMMER2	0.0425	90.7	**Poor**	0.0445	90.2	**Poor**
YRKMH	CHLA	ANNUAL	14.7550	79.4	**Poor**	-	-	-
YRKMH	CHLA	SPRING1	17.3400	73.0	**Poor**	-	-	-
YRKMH	CHLA	SPRING2	14.5400	74.4	**Poor**	-	-	-
YRKMH	CHLA	SUMMER1	15.3800	85.7	**Poor**	-	-	-
YRKMH	CHLA	SUMMER2	15.9750	85.3	**Poor**	-	-	-
YRKMH	TSS	ANNUAL	32.5000	85.6	**Poor**	74.7500	93.5	**Poor**
YRKMH	TSS	SPRING1	55.5000	92.2	**Poor**	88.5000	92.4	**Poor**
YRKMH	TSS	SPRING2	60.0000	92.1	**Poor**	96.5000	91.6	**Poor**
YRKMH	TSS	SUMMER1	24.5000	79.0	**Poor**	60.2500	91.0	**Poor**
YRKMH	TSS	SUMMER2	21.5000	72.0	**Poor**	36.5000	76.8	**Poor**
YRKMH	SECCHI	ANNUAL	0.5500	12.5	**Poor**	-	-	-
YRKMH	SECCHI	SPRING1	0.4500	14.1	**Poor**	-	-	-
YRKMH	SECCHI	SPRING2	0.4500	12.6	**Poor**	-	-	-
YRKMH	SECCHI	SUMMER1	0.5000	10.1	**Poor**	-	-	-
YRKMH	SECCHI	SUMMER2	0.5500	15.4	**Poor**	-	-	-
YRKMH	DO	SPRING1	-	-	-	8.2000	.	**Good**
YRKMH	DO	SPRING2	-	-	-	6.4250	.	**Good**
YRKMH	DO	SUMMER1	-	-	-	5.2475	.	**Good**
YRKMH	DO	SUMMER2	-	-	-	5.0800	.	**Good**

Table 3-11. Water quality trends in segment YRKMH (only significant trends are displayed).

a) Nutrient parameters

Segment	Layer	Parameter	'93 Trend p value	'93 Slope	'02 Trend p value	'02 Slope	Trend Comparison p value	Trend Comparison	Combined Trend p value	Combined Trend Direction
YRKMH	S	TN	0.0678	0.0154	0.1868	0.0086	0.4617	No Sign. Dif.	0.0008	**Degrading**
YRKMH	B	TN	0.0063	0.0208	0.3939	0.0080	0.0452	Sign. Dif.	0.0002	-
YRKMH	S	DIN	0.4248	0.0000	0.3161	0.0000	0.0535	No Sign. Dif.	0.8929	NS
YRKMH	B	DIN	0.4762	0.0000	0.1288	-0.0036	0.0228	Sign. Dif.	0.3965	-
YRKMH	S	TP	0.0000	0.0063	0.0101	0.0032	0.0008	Sign. Dif.	0.0000	-
YRKMH	B	TP	0.0001	0.0063	0.0062	0.0048	0.1745	No Sign. Dif.	0.0000	**Degrading**
YRKMH	S	PO4F	0.0000	0.0025	0.0000	0.0020	0.5323	No Sign. Dif.	0.0000	**Degrading**
YRKMH	B	PO4F	0.0000	0.0025	0.0000	0.0016	0.5014	No Sign. Dif.	0.0000	**Degrading**

b) Non-nutrient parameters

Segment	Parameter	Layer	Season	Baseline	Slope	% Change	% BDL	p Value	Direction
YRKMH	CHLA	S	Annual	9.59	0.1921	36.06	6.79	0.0218	**Degrading**
YRKMH	TSS	B	Annual	39.00	1.6771	64.50	0.51	0.0054	**Degrading**
YRKMH	DO	B	Summer1	5.08	0.0313	11.08	0.00	0.0287	**Improving**
YRKMH	SALINITY	S	Annual	12.43	0.1222	17.70	0.00	0.0278	**Increasing**

Table 3-12. SAV season water quality status in segment YRKMH (value is the median concentration; secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Value	Score	Status	Habitat Requirement
YRKMH	DIN	SAV1	0.081	48.7	**Fair**	**Meets**
YRKMH	PO4F	SAV1	0.022	81.6	**Poor**	**Fails**
YRKMH	CHLA	SAV1	14.54	76	**Poor**	**Meets**
YRKMH	TSS	SAV1	30	82	**Poor**	**Fails**
YRKMH	SECCHI	SAV1	0.5	13.4	**Poor**	**Fails**

Table 3-13. SAV Season Water quality trends in segment YRKMH (only significant trends are displayed).

a) Nutrient parameters

Segment	Layer	Parameter	‘93 Trend p value	‘93 Slope	‘02 Trend p value	‘02 Slope	Trend Comparison p value	Trend Comparison	Combined Trend p value	Combined Trend Direction
YRKMH	S	TN	0.0058	0.0233	0.3254	0.0081	0.0441	Sign. Dif.	0.0001	-
YRKMH	S	DIN	0.3612	0.0000	0.9047	0.0000	0.2873	No Sign. Dif.	0.4564	NS
YRKMH	S	TP	0.0000	0.0075	0.1071	0.0020	0.0006	Sign. Dif.	0.0000	-
YRKMH	S	PO4F	0.0000	0.0030	0.0001	0.0022	0.4058	No Sign. Dif.	0.0000	**Degrading**

b) Non-nutrient parameters (no significant trends detected)

Table 3-14. Water quality status in segment PMKOH (value is the median concentration, secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Svalue	Sscore	Sstatus	Bvalue	Bscore	Bstatus
PMKOH	TN	ANNUAL	0.7755	28.7	Good	1.1635	71.7	Poor
PMKOH	TN	SPRING1	0.8365	32.5	Good	1.4350	84.0	Poor
PMKOH	TN	SPRING2	0.8290	41.4	Good	1.2540	82.2	Poor
PMKOH	TN	SUMMER1	0.6960	25.3	Good	1.0010	65.6	Poor
PMKOH	TN	SUMMER2	0.6880	25.3	Good	0.9345	58.8	Poor
PMKOH	DIN	ANNUAL	0.2030	36.2	Good	0.1980	34.3	Good
PMKOH	DIN	SPRING1	0.2558	29.9	Good	0.2430	29.2	Good
PMKOH	DIN	SPRING2	0.2390	37.3	Good	0.2250	34.9	Good
PMKOH	DIN	SUMMER1	0.1635	55.2	Fair	0.1690	53.9	Fair
PMKOH	DIN	SUMMER2	0.1480	62.8	Poor	0.1630	65.7	Poor
PMKOH	TP	ANNUAL	0.0895	51.2	Fair	0.1708	79.6	Poor
PMKOH	TP	SPRING1	0.1112	56.9	Fair	0.1708	74.2	Poor
PMKOH	TP	SPRING2	0.1410	81.8	Poor	0.1708	75.6	Poor
PMKOH	TP	SUMMER1	0.0899	60.4	Poor	0.1785	81.8	Poor
PMKOH	TP	SUMMER2	0.0871	62.3	Poor	0.1593	76.1	Poor
PMKOH	PO4F	ANNUAL	0.0240	79.2	Poor	0.0230	74.3	Poor
PMKOH	PO4F	SPRING1	0.0170	59.8	Poor	0.0180	62.4	Poor
PMKOH	PO4F	SPRING2	0.0180	66.8	Poor	0.0180	65.2	Poor
PMKOH	PO4F	SUMMER1	0.0275	86.5	Poor	0.0275	81.6	Poor
PMKOH	PO4F	SUMMER2	0.0300	89.4	Poor	0.0320	87.7	Poor
PMKOH	CHLA	ANNUAL	7.5100	47.2	Fair	-	-	-
PMKOH	CHLA	SPRING1	5.1100	28.7	Good	-	-	-
PMKOH	CHLA	SPRING2	5.8000	29.7	Good	-	-	-
PMKOH	CHLA	SUMMER1	10.2250	48.3	Fair	-	-	-
PMKOH	CHLA	SUMMER2	9.9100	36.1	Good	-	-	-
PMKOH	TSS	ANNUAL	50.5000	74.7	Poor	113.0000	86.2	Poor
PMKOH	TSS	SPRING1	63.0000	73.6	Poor	160.0000	89.7	Poor
PMKOH	TSS	SPRING2	64.0000	79.3	Poor	161.0000	91.2	Poor
PMKOH	TSS	SUMMER1	28.0000	51.2	Fair	99.5000	80.3	Poor
PMKOH	TSS	SUMMER2	27.0000	56.5	Fair	77.0000	73.2	Poor
PMKOH	SECCHI	ANNUAL	0.4000	46.6	Fair	-	-	-
PMKOH	SECCHI	SPRING1	0.2000	10.5	Poor	-	-	-
PMKOH	SECCHI	SPRING2	0.3000	30.3	Poor	-	-	-
PMKOH	SECCHI	SUMMER1	0.4500	37.4	Poor	-	-	-
PMKOH	SECCHI	SUMMER2	0.5000	40.6	Poor	-	-	-
PMKOH	DO	SPRING1	-	-	-	8.7400	.	Good
PMKOH	DO	SPRING2	-	-	-	6.0700	.	Good
PMKOH	DO	SUMMER1	-	-	-	4.7250	.	Fair
PMKOH	DO	SUMMER2	-	-	-	4.6900	.	Fair

Table 3-15. Water quality trends in segment PMKOH (only significant trends are displayed).

a) Nutrient parameters

Segment	Layer	Parameter	'93 Trend p value	'93 Slope	'02 Trend p value	'02 Slope	Trend Comparison p value	Trend Comparison	Combined Trend p value	Combined Trend Direction
PMKOH	S	TN	0.0008	0.0300	1.0000	0.0001	0.0001	Sign. Dif.	0.0001	-
PMKOH	B	TN	0.0003	0.0533	0.0137	0.0446	0.1106	No Sign. Dif.	0.0000	**Degrading**
PMKOH	S	DIN	0.3289	0.0025	0.4635	-0.0021	0.0564	No Sign. Dif.	0.6896	NS
PMKOH	B	DIN	0.1913	0.0075	0.4548	-0.0034	0.0300	Sign. Dif.	0.5436	-
PMKOH	S	TP	0.0002	0.0075	0.1887	-0.0028	0.0000	Sign. Dif.	0.0034	-
PMKOH	B	TP	0.0002	0.0200	0.1126	0.0072	0.0146	Sign. Dif.	0.0000	-
PMKOH	S	PO4F	0.0012	0.0011	0.9334	0.0000	0.0017	Sign. Dif.	0.0007	-
PMKOH	B	PO4F	0.0436	0.0000	0.5058	0.0003	0.2300	No Sign. Dif.	0.0091	**Degrading**

b) Non-nutrient parameters

Segment	Parameter	Layer	Season	Baseline	Slope	% Change	% BDL	p Value	Direction
PMKOH	CHLA	S	Annual	6.38	0.0863	24.33	17.89	0.0027	**Degrading**
PMKOH	SECCHI	S	Annual	0.30	0.0000	0.00	0.00	0.0064	**Improving**
PMKOH	SALINITY	S	Annual	3.49	0.1400	72.21	0.00	0.0001	**Increasing**
PMKOH	SALINITY	B	Annual	4.31	0.1458	60.90	0.00	0.0002	**Increasing**

Table 3-16. SAV season water quality status in segment PMKOH (value is the median concentration; secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Value	Score	Status	Habitat Requirement
PMKOH	DIN	SAV1	0.179	46	**Fair**	-
PMKOH	PO4F	SAV1	0.026	84.8	**Poor**	**Fails**
PMKOH	CHLA	SAV1	9.91	51.4	**Fair**	**Meets**
PMKOH	TSS	SAV1	50.5	79.8	**Poor**	**Fails**
PMKOH	SECCHI	SAV1	0.4	37	**Poor**	**Fails**

Table 3-17. SAV Season Water quality trends in segment PMKOH (only significant trends are displayed).

a) Nutrient parameters

Segment	Layer	Parameter	'93 Trend p value	'93 Slope	'02 Trend p value	'02 Slope	Trend Comparison p value	Trend Comparison	Combined Trend p value	Combined Trend Direction
PMKOH	S	TN	0.0002	0.0368	0.6178	-0.0080	0.0000	Sign. Dif.	0.0001	-
PMKOH	S	DIN	0.0019	0.0150	1.0000	0.0000	0.0001	Sign. Dif.	0.0002	-
PMKOH	S	TP	0.0003	0.0100	0.0637	-0.0048	0.0000	Sign. Dif.	0.0257	-
PMKOH	S	PO4F	0.0000	0.0025	0.6137	0.0004	0.0000	Sign. Dif.	0.0000	-

b) Non-nutrient parameters

Segment	Layer	Season	Parameter	Baseline	Slope	% Change	p value	%BDL	Direction
PMKOH	S	SAV1	SALINITY	5.03	0.1008	36.08	0.0145	0.00	**Increasing**

Table 3-18. Water quality status in segment PMKTF (value is the median concentration, secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Svalue	Sscore	Sstatus	Bvalue	Bscore	Bstatus
PMKTF	TN	ANNUAL	0.7050	18.5	Good	0.7360	11.3	Good
PMKTF	TN	SPRING1	0.8455	47.8	Fair	0.7740	18.6	Good
PMKTF	TN	SPRING2	0.8440	41.7	Good	0.7520	12.8	Good
PMKTF	TN	SUMMER1	0.5870	6.8	Good	0.6360	3.9	Good
PMKTF	TN	SUMMER2	0.5850	6.3	Good	0.6220	3.8	Good
PMKTF	DIN	ANNUAL	0.3343	34.8	Good	0.2630	17.0	Good
PMKTF	DIN	SPRING1	0.3680	37.8	Good	0.3645	29.1	Good
PMKTF	DIN	SPRING2	0.3680	42.2	Fair	0.3645	30.5	Good
PMKTF	DIN	SUMMER1	0.1185	7.5	Good	0.1125	4.3	Good
PMKTF	DIN	SUMMER2	0.0910	5.7	Good	0.0760	2.9	Good
PMKTF	TP	ANNUAL	0.0772	29.9	Good	0.0794	24.4	Good
PMKTF	TP	SPRING1	0.0851	43.7	Fair	0.0910	39.0	Good
PMKTF	TP	SPRING2	0.0875	40.8	Good	0.0934	33.4	Good
PMKTF	TP	SUMMER1	0.0785	22.6	Good	0.0799	18.1	Good
PMKTF	TP	SUMMER2	0.0684	14.0	Good	0.0710	12.9	Good
PMKTF	PO4F	ANNUAL	0.0190	33.3	Good	0.0185	34.7	Good
PMKTF	PO4F	SPRING1	0.0270	53.4	Fair	0.0215	44.1	Fair
PMKTF	PO4F	SPRING2	0.0290	58.0	Fair	0.0285	57.5	Fair
PMKTF	PO4F	SUMMER1	0.0205	35.0	Good	0.0200	37.2	Good
PMKTF	PO4F	SUMMER2	0.0190	31.8	Good	0.0180	33.4	Good
PMKTF	CHLA	ANNUAL	3.1000	17.1	Good	-	-	-
PMKTF	CHLA	SPRING1	3.0250	17.2	Good	-	-	-
PMKTF	CHLA	SPRING2	3.1900	14.3	Good	-	-	-
PMKTF	CHLA	SUMMER1	5.8600	20.4	Good	-	-	-
PMKTF	CHLA	SUMMER2	6.7450	22.6	Good	-	-	-
PMKTF	TSS	ANNUAL	18.5000	64.5	Poor	25.6250	49.8	Fair
PMKTF	TSS	SPRING1	30.0000	83.4	Poor	28.5000	50.0	Fair
PMKTF	TSS	SPRING2	26.0000	79.5	Poor	27.0000	42.9	Fair
PMKTF	TSS	SUMMER1	16.2500	59.4	Poor	21.0000	35.2	Good
PMKTF	TSS	SUMMER2	14.0000	50.4	Fair	21.0000	39.5	Good
PMKTF	SECCHI	ANNUAL	0.6000	45.6	Fair	-	-	-
PMKTF	SECCHI	SPRING1	0.6000	42.5	Fair	-	-	-
PMKTF	SECCHI	SPRING2	0.5000	25.9	Poor	-	-	-
PMKTF	SECCHI	SUMMER1	0.6500	49.9	Fair	-	-	-
PMKTF	SECCHI	SUMMER2	0.7000	58.2	Fair	-	-	-
PMKTF	DO	SPRING1	-	-	-	8.0650	.	Good
PMKTF	DO	SPRING2	-	-	-	6.2300	.	Good
PMKTF	DO	SUMMER1	-	-	-	5.4600	.	Good
PMKTF	DO	SUMMER2	-	-	-	5.5750	.	Good

Table 3-19. Water quality trends in segment PMKTF (only significant trends are displayed).

a) Nutrient parameters

Segment	Layer	Parameter	'93 Trend p value	'93 Slope	'02 Trend p value	'02 Slope	Trend Comparison p value	Trend Comparison	Combined Trend p value	Combined Trend Direction
PMKTF	S	TN	0.4783	0.0060	0.0018	0.0249	0.0264	Sign. Dif.	0.0001	**Degrading**
PMKTF	B	TN	0.8753	0.0012	0.0955	0.0219	0.1510	No Sign. Dif.	0.0595	NS
PMKTF	S	DIN	0.4106	0.0038	1.0000	0.0000	0.3943	No Sign. Dif.	0.3528	NS
PMKTF	B	DIN	0.4542	0.0044	0.0748	-0.0048	0.0092	Sign. Dif.	0.3415	-
PMKTF	S	TP	0.0001	0.0042	0.0119	0.0031	0.0767	No Sign. Dif.	0.0000	**Degrading**
PMKTF	B	TP	0.0000	0.0059	0.0068	0.0033	0.0030	Sign. Dif.	0.0000	-
PMKTF	S	PO4F	0.0789	0.0000	0.0877	-0.0008	0.9057	No Sign. Dif.	0.0008	**Improving**
PMKTF	B	PO4F	0.0329	0.0000	0.0583	-0.0010	0.9001	No Sign. Dif.	0.0001	**Improving**

b) Non-nutrient parameters

Segment	Parameter	Layer	Season	Baseline	Slope	% Change	% BDL	p Value	Direction
PMKTF	TSS	S	Annual	14.00	0.2857	30.61	2.01	0.0452	**Degrading**
PMKTF	WTEMP	S	Annual	18.00	0.0714	7.14	0.00	0.0126	**Increasing**
PMKTF	WTEMP	B	Annual	19.10	0.0900	8.48	0.00	0.0067	**Increasing**
PMKTF	SALINITY	S	Annual	0.01	0.0000	0.00	0.00	0.0000	**Increasing**
PMKTF	SALINITY	B	Annual	0.01	0.0000	0.00	0.00	0.0000	**Increasing**

Table 3-20. SAV season water quality status in segment PMKTF (value is the median concentration; secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Value	Score	Status	Habitat Requirement
PMKTF	DIN	SAV1	0.186	15.5	**Good**	-
PMKTF	PO4F	SAV1	0.019	33.1	**Good**	**Meets**
PMKTF	CHLA	SAV1	4.845	20.7	**Good**	**Meets**
PMKTF	TSS	SAV1	18	58.6	**Poor**	**Fails**
PMKTF	SECCHI	SAV1	0.6	43.4	**Fair**	**Fails**

Table 3-21. SAV Season Water quality trends in segment PMKTF (only significant trends are displayed).

a) Nutrient parameters

Segment	Layer	Parameter	'93 Trend p value	'93 Slope	'02 Trend p value	'02 Slope	Trend Comparison p value	Trend Comparison	Combined Trend p value	Combined Trend Direction
PMKTF	S	TN	0.5122	0.0061	0.0066	0.0261	0.0602	No Sign. Dif.	0.0004	**Degrading**
PMKTF	S	DIN	0.0905	0.0132	1.0000	0.0000	0.0576	No Sign. Dif.	0.0576	NS
PMKTF	S	TP	0.0060	0.0040	0.3706	0.0013	0.0220	Sign. Dif.	0.0000	-
PMKTF	S	PO4F	0.1525	0.0000	0.1200	-0.0009	0.9630	No Sign. Dif.	0.0062	**Improving**

b) Non-nutrient parameters

Segment	Layer	Season	Parameter	Baseline	Slope	% Change	p value	%BDL	Direction
PMKTF	S	SAV1	TSS	12.25	0.3606	44.15	0.0413	2.31	**Degrading**
PMKTF	S	SAV1	WTEMP	22.88	0.0714	5.62	0.0296	0.00	**Increasing**
PMKTF	S	SAV1	SALINITY	0.01	0.0000	0.00	0.0000	0.00	**Increasing**

Table 3-22. Water quality status in segment MPNOH (value is the median concentration, secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Svalue	Sscore	Sstatus	Bvalue	Bscore	Bstatus
MPNOH	TN	ANNUAL	0.7270	21.3	Good	0.7680	18.6	Good
MPNOH	TN	SPRING1	0.9040	43.7	Fair	0.8370	19.2	Good
MPNOH	TN	SPRING2	0.8300	41.7	Good	0.8370	24.8	Good
MPNOH	TN	SUMMER1	0.7005	26.3	Good	0.7995	31.9	Good
MPNOH	TN	SUMMER2	0.7005	28.4	Good	0.8810	48.5	Fair
MPNOH	DIN	ANNUAL	0.1770	29.6	Good	0.1645	25.5	Good
MPNOH	DIN	SPRING1	0.1940	17.1	Good	0.1780	15.4	Good
MPNOH	DIN	SPRING2	0.1940	24.4	Good	0.1835	22.6	Good
MPNOH	DIN	SUMMER1	0.1590	53.8	Fair	0.1534	47.3	Fair
MPNOH	DIN	SUMMER2	0.1590	67.3	Poor	0.1498	59.6	Poor
MPNOH	TP	ANNUAL	0.1030	63.9	Poor	0.1208	55.3	Fair
MPNOH	TP	SPRING1	0.1575	84.3	Poor	0.1142	38.9	Good
MPNOH	TP	SPRING2	0.1325	75.9	Poor	0.1485	61.2	Poor
MPNOH	TP	SUMMER1	0.1030	74.2	Poor	0.1789	81.9	Poor
MPNOH	TP	SUMMER2	0.1019	77.3	Poor	0.1695	77.4	Poor
MPNOH	PO4F	ANNUAL	0.0215	73.6	Poor	0.0210	69.1	Poor
MPNOH	PO4F	SPRING1	0.0140	45.5	Fair	0.0170	58.5	Fair
MPNOH	PO4F	SPRING2	0.0180	66.8	Poor	0.0170	60.8	Poor
MPNOH	PO4F	SUMMER1	0.0310	90.2	Poor	0.0320	87.9	Poor
MPNOH	PO4F	SUMMER2	0.0320	91.0	Poor	0.0330	88.6	Poor
MPNOH	CHLA	ANNUAL	7.2250	44.7	Fair	-	-	-
MPNOH	CHLA	SPRING1	9.5600	62.0	Poor	-	-	-
MPNOH	CHLA	SPRING2	6.9800	40.5	Good	-	-	-
MPNOH	CHLA	SUMMER1	7.5500	24.6	Good	-	-	-
MPNOH	CHLA	SUMMER2	7.6400	17.2	Good	-	-	-
MPNOH	TSS	ANNUAL	31.5000	49.3	Fair	57.5000	57.2	Poor
MPNOH	TSS	SPRING1	56.0000	66.8	Poor	59.0000	42.9	Fair
MPNOH	TSS	SPRING2	44.0000	56.4	Fair	72.5000	58.6	Poor
MPNOH	TSS	SUMMER1	33.0000	62.0	Poor	90.0000	76.4	Poor
MPNOH	TSS	SUMMER2	30.0000	63.5	Poor	53.2500	52.7	Fair
MPNOH	SECCHI	ANNUAL	0.4000	46.6	Fair	-	-	-
MPNOH	SECCHI	SPRING1	0.4000	76.5	Good	-	-	-
MPNOH	SECCHI	SPRING2	0.3000	30.3	Poor	-	-	-
MPNOH	SECCHI	SUMMER1	0.4000	23.0	Poor	-	-	-
MPNOH	SECCHI	SUMMER2	0.4000	14.3	Poor	-	-	-
MPNOH	DO	SPRING1	-	-	-	8.2300	.	Good
MPNOH	DO	SPRING2	-	-	-	6.0650	.	Good
MPNOH	DO	SUMMER1	-	-	-	4.5700	.	Fair
MPNOH	DO	SUMMER2	-	-	-	4.4300	.	Fair

Table 3-23. Water quality trends in segment MPNOH (only significant trends are displayed).

a) Nutrient parameters

Segment	Layer	Parameter	'93 Trend p value	'93 Slope	'02 Trend p value	'02 Slope	Trend Comparison p value	Trend Comparison	Combined Trend p value	Combined Trend Direction
MPNOH	S	TN	0.0001	0.0230	0.1639	0.0105	0.0015	Sign. Dif.	0.0000	-
MPNOH	B	TN	0.0911	0.0217	0.4006	-0.0090	0.0048	Sign. Dif.	0.2745	-
MPNOH	S	DIN	0.0602	0.0079	0.9302	0.0000	0.0467	Sign. Dif.	0.0249	-
MPNOH	B	DIN	0.0444	0.0075	0.5504	-0.0002	0.0064	Sign. Dif.	0.1422	-
MPNOH	S	TP	0.0000	0.0071	0.3186	0.0027	0.0001	Sign. Dif.	0.0000	-
MPNOH	B	TP	0.0005	0.0100	0.4229	0.0028	0.0045	Sign. Dif.	0.0000	-
MPNOH	S	PO4F	0.0039	0.0000	0.2703	0.0005	0.0904	No Sign. Dif.	0.0001	**Degrading**
MPNOH	B	PO4F	0.0058	0.0000	0.1818	0.0005	0.1856	No Sign. Dif.	0.0001	**Degrading**

b) Non-nutrient parameters

Segment	Parameter	Layer	Season	Baseline	Slope	% Change	% BDL	p Value	Direction
MPNOH	CHLA	S	Annual	3.86	0.1439	67.16	24.50	0.0000	**Degrading**
MPNOH	DO	B	Summer1	5.05	0.0375	13.37	0.00	0.0456	**Improving**
MPNOH	WTEMP	S	Annual	20.50	0.0346	3.04	0.00	0.0488	**Increasing**
MPNOH	SALINITY	S	Annual	3.38	0.2125	113.17	0.00	0.0000	**Increasing**
MPNOH	SALINITY	B	Annual	4.31	0.2311	96.51	0.00	0.0000	**Increasing**

Table 3-24. SAV season water quality status in segment MPNOH (value is the median concentration; secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Value	Score	Status	Habitat Requirement
MPNOH	DIN	SAV1	0.159	38.9	**Good**	-
MPNOH	PO4F	SAV1	0.028	87.5	**Poor**	**Fails**
MPNOH	CHLA	SAV1	9.08	44.7	**Fair**	**Meets**
MPNOH	TSS	SAV1	36	60.8	**Poor**	**Fails**
MPNOH	SECCHI	SAV1	0.4	37	**Poor**	**Fails**

Table 3-25. SAV Season Water quality trends in segment MPNOH (only significant trends are displayed).

a) Nutrient parameters

Segment	Layer	Parameter	‘93 Trend p value	‘93 Slope	‘02 Trend p value	‘02 Slope	Trend Comparison p value	Trend Comparison	Combined Trend p value	Combined Trend Direction
MPNOH	S	TN	0.0000	0.0325	0.3159	0.0105	0.0000	Sign. Dif.	0.0000	-
MPNOH	S	DIN	0.0005	0.0150	1.0000	0.0000	0.0000	Sign. Dif.	0.0001	-
MPNOH	S	TP	0.0000	0.0075	0.8273	0.0016	0.0000	Sign. Dif.	0.0000	-
MPNOH	S	PO4F	0.0004	0.0021	0.2728	0.0007	0.0090	Sign. Dif.	0.0000	-

b) Non-nutrient parameters

Segment	Layer	Season	Parameter	Baseline	Slope	% Change	p value	%BDL	Direction
MPNOH	S	SAV1	CHLA	7.42	0.1778	43.15	0.0061	16.36	**Degrading**
MPNOH	S	SAV1	TSS	19.00	0.5000	47.37	0.0498	0.69	**Degrading**
MPNOH	S	SAV1	SALINITY	4.27	0.1710	72.04	0.0018	0.00	**Increasing**

Table 3-26. Water quality status in segment MPNTF (value is the median concentration, secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Svalue	Sscore	Sstatus	Bvalue	Bscore	Bstatus
MPNTF	TN	ANNUAL	0.5830	8.7	Good	0.6300	5.4	Good
MPNTF	TN	SPRING1	0.6670	18.8	Good	0.6695	8.1	Good
MPNTF	TN	SPRING2	0.7005	19.8	Good	0.6990	8.3	Good
MPNTF	TN	SUMMER1	0.5630	5.7	Good	0.6180	3.3	Good
MPNTF	TN	SUMMER2	0.5430	4.6	Good	0.5600	2.3	Good
MPNTF	DIN	ANNUAL	0.2040	13.6	Good	0.1920	8.0	Good
MPNTF	DIN	SPRING1	0.2465	12.3	Good	0.2540	8.6	Good
MPNTF	DIN	SPRING2	0.2550	17.0	Good	0.2655	10.6	Good
MPNTF	DIN	SUMMER1	0.1040	5.7	Good	0.1050	3.7	Good
MPNTF	DIN	SUMMER2	0.0920	5.8	Good	0.0920	4.3	Good
MPNTF	TP	ANNUAL	0.0681	22.0	Good	0.0722	19.2	Good
MPNTF	TP	SPRING1	0.0666	24.8	Good	0.0608	12.9	Good
MPNTF	TP	SPRING2	0.0745	25.2	Good	0.0831	24.6	Good
MPNTF	TP	SUMMER1	0.0820	25.7	Good	0.0840	20.6	Good
MPNTF	TP	SUMMER2	0.0820	24.5	Good	0.0780	17.0	Good
MPNTF	PO4F	ANNUAL	0.0190	33.3	Good	0.0193	36.6	Good
MPNTF	PO4F	SPRING1	0.0200	39.1	Good	0.0220	45.4	Fair
MPNTF	PO4F	SPRING2	0.0360	68.9	Poor	0.0340	66.6	Poor
MPNTF	PO4F	SUMMER1	0.0255	44.6	Fair	0.0260	49.6	Fair
MPNTF	PO4F	SUMMER2	0.0160	25.6	Good	0.0170	31.0	Good
MPNTF	CHLA	ANNUAL	2.4900	12.4	Good	-	-	-
MPNTF	CHLA	SPRING1	1.8500	7.0	Good	-	-	-
MPNTF	CHLA	SPRING2	2.6300	10.5	Good	-	-	-
MPNTF	CHLA	SUMMER1	5.1350	17.0	Good	-	-	-
MPNTF	CHLA	SUMMER2	5.2700	16.2	Good	-	-	-
MPNTF	TSS	ANNUAL	11.0000	35.3	Good	13.0000	17.5	Good
MPNTF	TSS	SPRING1	15.0000	41.7	Good	17.0000	21.3	Good
MPNTF	TSS	SPRING2	15.0000	44.4	Fair	14.6250	12.4	Good
MPNTF	TSS	SUMMER1	8.0000	17.0	Good	9.5000	6.0	Good
MPNTF	TSS	SUMMER2	7.0000	13.2	Good	8.0000	4.9	Good
MPNTF	SECCHI	ANNUAL	0.6000	45.6	Fair	-	-	-
MPNTF	SECCHI	SPRING1	0.6000	42.5	Fair	-	-	-
MPNTF	SECCHI	SPRING2	0.6000	43.4	Fair	-	-	-
MPNTF	SECCHI	SUMMER1	0.6500	49.9	Fair	-	-	-
MPNTF	SECCHI	SUMMER2	0.7000	58.2	Fair	-	-	-
MPNTF	DO	SPRING1	-	-	-	8.3700	.	Good
MPNTF	DO	SPRING2	-	-	-	6.5650	.	Good
MPNTF	DO	SUMMER1	-	-	-	5.4350	.	Good
MPNTF	DO	SUMMER2	-	-	-	5.1100	.	Good

Table 3-27. Water quality trends in segment MPNTF (only significant trends are displayed).

a) Nutrient parameters

Segment	Laye	Paramete	‘93 Trend p value	‘93 Slope	‘02 Trend p value	‘02 Slope	Trend Comparison p value	Trend Comparison	Combine d Trend p value	Combined Trend Direction
MPNTF	S	TN	0.5504	0.0050	0.6623	0.0035	0.8017	No Sign. Dif.	0.2411	NS
MPNTF	B	TN	0.1074	-0.0065	0.3774	0.0068	0.0057	Sign. Dif.	0.3412	-
MPNTF	S	DIN	0.0764	0.0063	0.6838	0.0000	0.0202	Sign. Dif.	0.1453	-
MPNTF	B	DIN	0.2408	0.0040	0.4666	0.0000	0.0439	Sign. Dif.	0.6145	-
MPNTF	S	TP	0.0004	0.0020	0.1684	0.0021	0.0167	Sign. Dif.	0.0000	-
MPNTF	B	TP	0.0935	0.0008	0.1411	0.0021	0.7263	No Sign. Dif.	0.0009	**Degrading**
MPNTF	S	PO4F	0.5407	0.0000	0.0147	-0.0015	0.0022	Sign. Dif.	0.0617	-
MPNTF	B	PO4F	0.1021	0.0000	0.0279	-0.0014	0.5001	No Sign. Dif.	0.0001	**Improving**

b) Non-nutrient parameters

Segment	Layer	Season	Parameter	Baseline	Slope	% Change	p value	%BDL	Direction
MPNTF	TSS	S	Annual	6.00	0.1429	35.71	25.87	0.0203	**Degrading**
MPNTF	SECCHI	S	Annual	1.00	-0.0091	-16.36	0.00	0.0126	**Degrading**
MPNTF	WTEMP	S	Annual	17.50	0.1167	12.00	0.00	0.0017	**Increasing**
MPNTF	WTEMP	B	Annual	18.58	0.1256	12.17	0.00	0.0004	**Increasing**
MPNTF	SALINITY	S	Annual	0.01	0.0000	0.00	0.00	0.0000	**Increasing**
MPNTF	SALINITY	B	Annual	0.01	0.0000	0.00	0.00	0.0000	**Increasing**

Table 3-28. SAV season water quality status in segment MPNTF (value is the median concentration; secchi in meters, chlorophyll *a* in F g/l, all other parameters in mg/l).

Segment	Parameter	Season	Value	Score	Status	Habitat Requirement
MPNTF	DIN	SAV1	0.16	11.4	Good	-
MPNTF	PO4F	SAV1	0.024	43.5	Fair	Fails
MPNTF	CHLA	SAV1	3.97	15.7	Good	Meets
MPNTF	TSS	SAV1	8	14.5	Good	Meets
MPNTF	SECCHI	SAV1	0.7	59.8	Good	Fails

Table 3-29. SAV Season Water quality trends in segment MPNTF (only significant trends are displayed).

a) Nutrient parameters

Segment	Layer	Parameter	'93 Trend p value	'93 Slope	'02 Trend p value	'02 Slope	Trend Comparison p value	Trend Comparison	Combined Trend p value	Combined Trend Direction
MPNTF	S	TN	0.0000	-0.0004	0.6429	-0.0028	0.6859	No Sign. Dif.	0.6030	NS
MPNTF	S	DIN	0.0136	0.0100	0.5983	0.0000	0.0009	Sign. Dif.	0.0311	-
MPNTF	S	TP	0.0115	0.0017	0.9562	-0.0001	0.0030	Sign. Dif.	0.0060	-
MPNTF	S	PO4F	0.1370	0.0006	0.0229	-0.0018	0.0001	Sign. Dif.	0.4791	-

b) Non-nutrient parameters

Segment	Layer	Season	Parameter	Baseline	Slope	% Change	p value	%BDL	Direction
MPNTF	S	SAV1	WTEMP	23.38	0.1375	10.59	0.0026	0.00	Increasing
MPNTF	S	SAV1	SALINITY	0.01	0.0000	0.00	0.0021	0.00	Increasing

Literature Cited

Alden, R.W. III., R.S. Birdsong, D.M. Dauer, H.G. Marshall and R.M. Ewing, 1992a. Virginia Chesapeake Bay water quality and living resources monitoring programs: Comprehensive technical report, 1985-1989. Applied Marine Research Laboratory Technical Report No. 848, Norfolk VA. Final Report to the Virginia State Water Control Board, Richmond, Virginia.

Alden, R.W. III, D.M. Dauer, J.A. Ranasinghe, L.C. Scott, and R.J. Llansó. 2002. Statistical verification of the Chesapeake Bay Benthic Index of Biotic Integrity. *Environmetrics* 13: 473- 498.

Alden, R.W. III., R.M. Ewing, S.W. Sokolowski, J.C. Seibel, 1991. Long-term trends in water quality of the Lower Chesapeake Bay. p. 502-522, In: New Perspectives in the Chesapeake System: A Research and Management Partnership. Proceedings of a Conference. Chesapeake Research Consortium Publication No. 137, Solomons, MD., pp. 780.

Alden, R.W. III. and M.F. Lane, 1996. An assessment of the power and robustness of the Chesapeake Bay Program Water Quality Monitoring Programs: Phase III - Refinement evaluations. Applied Marine Research Laboratory Technical Report No. 3002, Norfolk VA. Final Report to the Virginia State Water Control Board, Richmond, Virginia.

Alden, R.W. III., M.F. Lane, H. Lakkis, J.C. Seibel, 1992b. An assessment of the power and robustness of the Chesapeake Bay Program Water Quality Monitoring Programs: Phase I - Preliminary evaluations. Applied Marine Research Laboratory Technical Report No. 846, Norfolk VA. Final Report to the Virginia State Water Control Board, Richmond, Virginia.

Alden, R.W. III., M.F. Lane, H. Lakkis, J.C. Seibel, 1994. An assessment of the power and robustness of the Chesapeake Bay Program Water Quality Monitoring Programs: Phase II - Refinement evaluations. Applied Marine Research Laboratory Technical Report No. 965, Norfolk VA. Final Report to the Virginia State Water Control Board, Richmond, Virginia.

Alden, R.W. III, S.B. Weisberg, J.A. Ranasinghe and D.M. Dauer. 1997. Optimizing temporal sampling strategies for benthic environmental monitoring programs. *Marine Pollution Bulletin* 34: 913-922.

Batuik, R.A., R.J. Orth, K.A. Moore, W.C. Dennison, J.C. Stevenson, L.W. Staver, V. Carter, N.B. Rybicki, R.E. Hickman, S. Kollar, S. Beiber, and P. Heasly, 1992. Chesapeake Bay Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets: A Technical Synthesis. CBP/TRS83/92. US Environmental Protection Agency Chesapeake Bay Program. Annapolis, MD., pp. 186.

Batuik, R.A., P. Bergstrom, M. Kemp, E. Koch, L. Murray, J.C. Stevenson, R. Bartleson, V. Carter, N.B. Rybicki, J.M. Landwehr, C. Gallegos, L. Karrh, M. Naylor, D. Wilcox, K.A. Moore, S. Ailstock, and M. Teichberg, 2000. Chesapeake Bay Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets: A Second Technical Synthesis. US Environmental Protection Agency Chesapeake Bay Program , pp. 217.

Carpenter, K.E. and M.F. Lane, 1998. Zooplankton Status and Trends in the Virginia Tributaries and Chesapeake Bay: 1985-1996. AMRL Technical Report No. 3064. Final Report to the Virginia Department of Environmental Quality, Richmond, Virginia. Applied Marine Research Laboratory, Norfolk VA., pp. 28.

Dauer, D.M., 1993. Biological criteria, environmental health and estuarine macrobenthic community structure. *Mar. Pollut. Bull.* 26: 249-257.

Dauer, D.M. 1997. Virginia Chesapeake Bay Monitoring Program. Benthic Communities Report. 1985-1996. Final Report to the Virginia Department of Environmental Quality, pp. 92.

Dauer, D.M. 1999. Baywide benthic community condition based upon 1997 random probability based sampling and relationships between benthic community condition, water quality, sediment quality, nutrient loads and land use patterns in Chesapeake Bay. Final report to the Virginia Department of Environmental Quality, pp.18.

Dauer, D.M., M. F. Lane, H.G. Marshall, and K.E. Carpenter. 1998a. Status and trends in water quality and living resources in the Virginia Chesapeake Bay: 1985-1997. Final report to the Virginia Department of Environmental Quality, pp. 86.

Dauer, D.M., M. F. Lane, H.G. Marshall, K.E. Carpenter and J.R. Donat. 2002. Status and trends in water quality and living resources in the Virginia Chesapeake Bay: 1985-2000. Final report to the Virginia Department of Environmental Quality, pp. 149.

Dauer, D.M., Luckenbach, M.W. and A.J. Rodi, Jr., 1993. Abundance biomass comparison (ABC method):effects of an estuarine gradient, anoxic/hypoxic events and contaminated sediments. *Mar. Biol.* 116: 507-518.

Dauer, D.M., H.G. Marshall, K.E. Carpenter, M.F. Lane, R.W. Alden III, K.K. Nesius and L.W. Haas, 1998b. Virginia Chesapeake Bay Water Quality and Living Resources Monitoring Programs: Executive Report, 1985-1996. Final Report to the Virginia Department of Environmental Quality, Richmond, Virginia. Applied Marine Research Laboratory, Norfolk VA., pp. 28.

Dauer, D.M. and A.J. Rodi, Jr. 1998a. Benthic biological monitoring of the lower Chesapeake Bay. 1996 Random Sampling. Virginia Department of Environmental Quality, Chesapeake Bay Program, pp. 137.

Dauer, D.M. and A.J. Rodi, Jr. 1998b. Benthic biological monitoring of the lower Chesapeake Bay. 1997 Random Sampling. Virginia Department of Environmental Quality, Chesapeake Bay Program, pp. 132.

Dauer, D.M. and A.J. Rodi, Jr. 1999. Baywide benthic community condition based upon 1998 random probability based sampling. Final report to the Virginia Department of Environmental Quality, pp. 126.

Dauer, D.M. and A.J. Rodi, Jr. 2001. Baywide benthic community condition based upon 1999 random probability based sampling. Final report to the Virginia Department of Environmental Quality, pp. 154.

Dauer, D.M. and A.J. Rodi, Jr. 2002. Baywide benthic community condition based upon 2000 random probability based sampling. Final report to the Virginia Department of Environmental Quality, pp. 151.

Dauer, D.M., Rodi, Jr., A.J. and J.A. Ranasinghe, 1992. Effects of low dissolved oxygen events on the macrobenthos of the lower Chesapeake Bay. *Estuaries* 15: 384-391.

Donat, J.R. and S.C. Doughten, 2003. Work/Quality Assurance Project Plan for Chesapeake Bay Mainstem and Elizabeth River Water Quality Monitoring Program. Revision 5. Old Dominion University, Norfolk, VA. Prepared for the Virginia Department of Environmental Quality, Richmond, VA., pp. 469.

Folk, R.L. 1974. Petrology of sedimentary rocks. Hemphill Publishing Co., Austin, Texas, pp. 182.

Gilbert, R.O., 1987. Statistical methods for environmental pollution monitoring. Van Nostrand Reinhold Co., New York, pp. 320.

Lane, M.F., R.W. Alden III, and A.W. Messing, 1998. Water Quality Status and Trends in the Virginia Tributaries and Chesapeake Bay: 1985-1996. AMRL Technical Report No. 3067. Final Report to the Virginia Department of Environmental Quality, Richmond, Virginia. Applied Marine Research Laboratory, Norfolk VA., pp. 116.

Margalef, R., 1958. Information theory in ecology. *Gen. Syst*. 3:36-71.

Marshall, H.G. 1994. Chesapeake Bay phytoplankton: I. Composition. *Proc. Biological Soc. Washington*, 107:573-585.

Marshall, H.G. 1995. Succession of dinoflagellate blooms in the Chesapeake Bay, U.S.A. In: P. Lassus et al. (eds.) Harmful Marine Algal Blooms, Lavoisier, Intercept, Ltd., pp. 615-620.

Marshall, H.G. 1996. Toxin producing phytoplankton in Chesapeake Bay. *Virginia J. Science*, 47:29-37.

Marshall, H.G. and R.W. Alden. 1990. A comparison of phytoplankton assemblages and environmental relationships in three estuarine rivers of the lower Chesapeake Bay. *Estuaries*, 13:287-300.

Marshall, H.G. and L. Burchardt. 1998. Phytoplankton composition within the tidal freshwater region of the James River, Virginia. *Proc. Biol Soc. Wash.* 111:720-730.

Marshall, H.G. and K.K. Nesius. 1996. Phytoplankton composition in relation to primary production in Chesapeake Bay. *Marine Biology*, 125:611-617.

Marshall, H.G., K.K. Nesius, and M.F. Lane, 1998. Phytoplankton Status and Trends in the Virginia Tributaries and Chesapeake Bay: 1985-1996. AMRL Technical Report No. 3063. Final Report to the Virginia Department of Environmental Quality, Richmond, Virginia. Applied Marine Research Laboratory, Norfolk VA., pp. 33.

Park, G.S. and H,G. Marshall. 1993. Microzooplankton in the Lower Chesapeake Bay, and the tidal Elizabeth, James, and York Rivers. *Virginia J. Science*, 44:329-340.

Ranasinghe, J.A., S.B. Weisberg, D.M. Dauer, L.C. Schaffner, R.J. Diaz and J.B. Frithsen, 1994. Chesapeake Bay benthic community restoration goals. Report for the U.S. Environmental Protection Agency, Chesapeake Bay Office and the Maryland Department of Natural Resources, pp. 49.

Symposium on the Classification of Brackish Waters, 1958. The Venice system for the classification of marine waters according to salinity. *Oikos* 9:11-12.

Venrick,E.L. 1978. How many cells to count. In: A. Sournia (ed.) Phytoplankton Manual. UNESCO Publ. Page Brothers Ltd., pp. 167-180.

Weisberg, S.B., A.F. Holland, K.J. Scott, H.T. Wilson, D.G. Heimbuch, S.C. Schimmel, J.B. Frithsen, J.F. Paul, J.K. Summers, R.M. Valente, J. Gerritsen, and R.W. Latimer. 1993. EMAP-Estuaries, Virginian Province 1990: Demonstration Project Report. EPA/600/R-92/100. U.S. Environmental Protection Agency, Washington, D.C.

Weisberg, S.B., J.A. Ranasinghe, D.M. Dauer, L.C. Schaffner, R.J. Diaz and J.B. Frithsen, 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. *Estuaries*. 20: 149-158.

Glossary of Important Terms

Anoxic - condition in which the water column is characterized by a complete absence of oxygen. Anoxic conditions typically result from excessive decomposition of organic material by bacteria, high respiration by phytoplankton, stratification of the water column due to salinity or temperature effects or a combination of these factors. Anoxic conditions can result in fish kills or localized extinction of benthic communities.

Anthropogenic - resulting from or generated by human activities.

Benthos - refers to organisms that dwell on or within the bottom. Includes both hard substratum habitats (e.g. oyster reefs) and sedimentary habitats (sand and mud bottoms).

B-IBI - the benthic index of biotic integrity of Weisberg et al. (1997). The B-IBI is a multi-metric index that compares the condition of a benthic community to reference conditions.

Biological Nutrient Removal (BNR) - a temperature dependent process in which the ammonia nitrogen present in wastewater is converted by bacteria first to nitrate nitrogen and then to nitrogen gas. This technique is used to reduce the concentration of nitrogen in sewage treatment plant effluents.

Biomass - a quantitative estimate of the total mass of organisms for a particular population or community within a given area at a given time. Biomass for phytoplankton is measured as the total carbon within a liter of water. Biomass for the benthos is measured as the total ash-free dry weight per square meter of sediment habitat.

Chlorophyll *a* - a green pigment found in plant cells that functions as the receptor for energy in the form of sunlight. This energy is used in the production of cellular materials for growth and reproduction in plants. Chlorophyll *a* concentrations are measured in Φg/L and are used as estimate of the total biomass of phytoplankton cells in the water column. In general, high levels of chlorophyll *a* concentrations are believed to be indicative of excessive growth of phytoplankton resulting from excess nutrients such as nitrogen and phosphorus in the water column.

Calanoid copepod - crustaceans of the subclass Copepoda and order Calanoida that are the dominant group of the mesozooplankton in marine systems. Copepods in this group (e.g. *Acartia tonsa*) are one of the most important consumers of phytoplankton in estuarine systems.

Chlorophytes - algae belonging to the division Chlorophyta often referred to as true "green algae." Chlorophytes occur in unicellular, colonial and filamentous forms and are generally more common in tidal freshwater and oligohaline portions of estuaries.

Cladocerans - crustaceans of the class Branchipoda and class Cladocera commonly referred to as "water fleas." Although cladocerans are primarily found in tidal freshwater areas in estuaries, blooms of marine cladocerans periodically occur in higher salinity areas. Some smaller species such as *Bosmina longirostris* are believed to be indicators of poor water quality conditions.

Cryptomonads -algae belonging to the division Cryptophyta that have accessory pigments in addition to chlorophyll *a* which give these small flagellated cells a red, brown or yellow color.

Cyanobacteria - algae belonging to the division Cyanophycea that are procaryotic and that occur in single-celled, filamentous and colonial forms. In general, high concentrations of cyanobacteria are considered to be indicative of poor water quality.

Cyclopoid copepod - crustaceans of the subclass Copepoda and order Cyclopoida that are the dominant group of the mesozooplankton in marine systems. Copepods in this group (e.g. *Mesocyclops edax*) are one of the most important consumers of phytoplankton in estuarine systems.

Diatoms - algae belonging to the division Bacillariophyta that have a cell wall that is composed primarily of silica and that consists of two separate halves. Most diatoms are single-celled but some are colonial and filamentous forms. Diatoms are generally considered to be indicative of good water quality and are considered to be appropriate food for many zooplankton.

Dinoflagellates - biflagellated, predominately unicellular protists that are capable of performing photosynthesis. Many dinoflagellates are covered with cellulose plates or with a series of membranes. Some dinoflagellates periodically reproduce in large numbers causing blooms that are often referred to as "red tides." Certain species produce toxins and blooms of these forms have been implicated in fish kills. High concentrations of dinoflagellates are generally considered to be indicative of poor water quality.

Dissolved oxygen (DO) - the concentration of oxygen in solution in the water column, measured in mg/L. Most organisms rely on oxygen for cellular metabolism and as a result low levels of dissolved oxygen adversely affect important living resources such as fish and the benthos. In general, dissolved oxygen levels decrease with increasing pollution.

Dissolved inorganic nitrogen (DIN) - the concentration of inorganic nitrogen compounds including ammonia (NH_4), nitrates (NO_3) and nitrites (NO_2) in the water column measured in mg/L. These dissolved inorganic forms of nitrogen are directly available for uptake by phytoplankton by diffusion without first undergoing the process of decomposition. High concentrations of dissolved inorganic nitrogen can result in excessive growth of phytoplankton that in turn can adversely affect other living resources.

Dissolved inorganic phosphorus (PO4F) - the concentration of inorganic phosphorus compounds consisting primarily of orthophosphates (PO_4), The dissolved inorganic forms of phosphorus are directly available for uptake by phytoplankton by diffusion without first undergoing the process of decomposition. High concentrations of dissolved inorganic phosphorus can result in excessive growth of phytoplankton that in turn can adversely affect other living resources.

Estuary - A semi-enclosed body of water that has a free connection with the open sea and within which seawater is diluted measurably with freshwater derived from land drainage.

Eucaryote - organisms the cells of which have discrete organelles and a nucleus separated from the cytoplasm by a membrane.

Fall-line - location of the maximum upstream extent of tidal influence in an estuary typically characterized by a waterfall.

Fixed Point Stations - stations for long-term trend analysis whose location is unchanged over time.

Flow adjusted concentration (FAC) - concentration value that has been recalculated to remove the variation caused by freshwater flow into a stream. By removing variation caused by flow, the effects of other factors such as nutrient management strategies can be assessed.

Holoplankton - zooplankton such as copepods or cladocerans that spend their entire life cycle within the water column.

Habitat - a local environment that has a community distinct from other such habitat types. For the B-IBI of Chesapeake Bay seven habitat types were defined as combinations of salinity and sedimentary types - tidal freshwater, oligohaline, low mesohaline, high mesohaline sand, high mesohaline mud, polyhaline sand and polyhaline mud.

Hypoxic - condition in which the water column is characterized by dissolved oxygen concentrations less than 2 mg/L but greater than 0 mg/L. Hypoxic conditions typically result from excessive decomposition of organic material by bacteria, high respiration by phytoplankton, stratification of the water column due to salinity or temperature effects or a combination of these factors. Hypoxic conditions can result in fish kills or localized extinction of benthic communities.

Light attenuation (KD) - Absorption, scattering, or reflection of light by dissolved or suspended material in the water column expressed as the change in light extinction per meter of depth. Light attenuation reduces the amount of light available to submerged aquatic vegetation.

Loading - the total mass of contaminant or nutrient added to a stream or river generally expressed in lbs/yr.

Macrobenthos - a size category of benthic organisms that are retained on a mesh of 0.5 mm.

Meroplankton - temporary zooplankton consisting of the larval stages of organisms whose adult stages are not planktonic.

Mesohaline - refers to waters with salinity values ranging between 0.5 and 18.0 ppt.

Mesozooplankton - zooplankton with a maximum dimension ranging between 63 Φm and 2000 Φm. This size category consists primarily of adult stages of copepods, cladocerans, mysid shrimp, and chaetognaths, as well as, the larval stages of a variety of invertebrates and fish.

Metric - a parameter or measurement of community structure (e.g., abundance, biomass, species diversity).

Microzooplankton - zooplankton with a maximum dimension ranging between 2 Φm and 63 Φm. This size category consists primarily of single-celled protozoans, rotifers and the larval stages of copepods, cladocerans and other invertebrates.

Nauplii - earliest crustacean larval stage characterized by a single simple eye and three pairs of appendages.

Non-point source - a source of pollution that is distributed widely across the landscape surrounding a water body instead of being at a fixed location (e.g. run-off from residential and agricultural land).

Oligohaline - refers to waters with salinity values ranging between 0.5 and 5.0 ppt.

Oligotrich - protists of the phylum Ciliophora and order Oligotricha. These ciliates are important predators of small phytoplankton in marine systems.

Percent of light at the leaf surface (PLL) - the percentage of light at the surface of the water column that reaches the surface of the leaves of submerged aquatic vegetation generally estimated for depths of 0.5 m and 1.0 m. Without sufficient light at the leaf surface, submerged aquatic plants cannot perform photosynthesis and hence cannot grow or reproduce.

Phytoplankton - that portion of the plankton capable of producing its own food by photosynthesis. Typical members of the phytoplankton include diatoms, dinoflagellates and chlorophytes.

Picoplankton - phytoplankton with a diameter between 0.2 and 2.0 Φm in diameter. Picoplankton consists primarily of cyanobacteria and high concentrations of picoplankton are generally considered to be indicative of poor water quality conditions.

Pielou's evenness - an estimate of the distribution of proportional abundances of individual species within a community. Evenness (J) is calculated as follows: $J=H'/\ln S$ where H' is the Shannon - Weiner diversity index and S is the number of species.

Plankton - aquatic organisms that drift within and that are incapable of movement against water currents. Some plankton have limited locomotor ability that allows them to change their vertical position in the water column.

Point source - a source of pollution that is concentrated at a specific location such as the outfall of a sewage treatment plant or factory.

Polyhaline - refers to waters with salinity values ranging between 18.0 and 30 ppt.

Primary productivity - the rate of production of living material through the process of photosynthesis that for phytoplankton is typically expressed in grams of carbon per liter of water per hour. High rates of primary productivity are generally considered to be related to excessive concentrations of nutrients such as nitrogen and phosphorus in the water column.

Probability based sampling - all locations within a stratum have an equal chance of being sampled. Allows estimation of the percent of the stratum meeting or failing the benthic restoration goals.

Procaryote - organisms the cells of which do not have discrete organelles or a nucleus (e.g. Cyanobacteria).

Pycnocline - a rapid change in salinity in the water column indicating stratification of water with depth resulting from either changes in salinity or water temperature.

Random Station - a station selected randomly within a stratum. In every succeeding sampling event new random locations are selected.

Recruitment - The successful dispersal settlement and development of larval forms of plants or animal to a reproducing adult.

Reference condition - the structure of benthic communities at reference sites.

Reference sites - sites determined to be minimally impacted by anthropogenic stress. Conditions at theses sites are considered to represent goals for restoration of impacted benthic communities. Reference sites were selected by Weisberg et al. (1997) as those outside highly developed watersheds, distant from any point-source discharge, with no sediment contaminant effect, with no low dissolved oxygen effect and with a low level of organic matter in the sediment.

Restoration Goal - refers to obtaining an average B-IBI value of 3.0 for a benthic community indicating that values for metrics approximate the reference condition.

Riparian Buffer - An area of trees and shrubs a minimum of 100 feet wide located up gradient, adjacent, and parallel to the edge of a water feature which serves to: 1) reduce excess amounts of sediment, organic matter, nutrients, and other pollutants in surface runoff, 2) reduce soluble pollutants in shallow ground water flow, 3) create shade along water bodies to lower aquatic temperatures, 4) provide a source of detritus and large woody debris aquatic organisms, 5) provide riparian habitat and corridors for wildlife, and 6) reduce erosion of streambanks and shorelines

Rotifer - small multicellular planktonic animal of phylum Rotifera. These organisms are a major component of the microzooplankton and are major consumers of phytoplankton. High densities of rotifers are believed to be indicative of high densities of small phytoplankton such as cyanobacteria and as such are believed to be indicative of poor water quality.

Salinity - the concentration of dissolved salts in the water column measured in mg/L, ppt or psu. The composition and distribution of plant and animal communities is directly affected by salinity in estuarine systems. The effects of salinity on living resources must be taken into consideration when interpreting the potential effects of human activities on living resources.

Sarcodinians - single celled protists of the subphylum Sarcodina that includes amoeba and similar forms, characterized by possession of pseudopodia. Planktonic forms of sarcodinians typically have a external shell or test constructed of detrital or sedimentary particles and are important consumers of phytoplankton.

Secchi depth - the depth of light penetration expressed in meters as measured using a secchi disk. Light penetration depth directly affects the growth and recruitment of submerge aquatic vegetation.

Shannon Weiner diversity index - a measure of the number of species within a community and the relative abundances of each species. The Shannon Weiner index is calculated as follows:

$$H' = -\sum_{i=1}^{s} p_i \log_2 p_i$$

where p_i is the proportion of the *i*th species and S is the number of species.

Stratum - a geographic region of unique ecological condition or managerial interest.

Submerged aquatic vegetation (SAV) - rooted vascular plants (e.g. eelgrass, widgeon grass, sago pondweed) that grow in shallow water areas. SAV are important in marine environments because they serve as major food source, provide refuge for juvenile crabs and fish, stabilize sediments preventing shoreline erosion and excessive suspended materials in the water column, and produce oxygen in the water column.

Threshold - a value of a metric that determines the B-IBI scoring. For all metrics except abundance and biomass, two thresholds are used - the lower 5^{th} percentile and the 50^{th} percentile (median) of the distribution of values at reference sites. Samples with metric values less than the lower 5^{th} percentile are scored as a 1. Samples with values between the 5^{th} and 50^{th} metrics are scored as 3 and values greater than the 50^{th} percentile are scored as 5. For abundance and biomass, values below the 5^{th} and above the 95^{th} percentile are scored as 1, values between the 5^{th} and 25^{th} and the 75^{th} and 95^{th} percentiles are scored as 3 and values between the 25^{th} and 75^{th} percentiles are scored as 5.

Tidal freshwater - refers to waters with salinity values ranging between 0 and 0.5 ppt that are located in the upper reaches of the estuary at or just below the maximum upstream extent of tidal influence.

Tintinnid - protists of phylum Ciliophora and order Oligotricha. These ciliates are important predators of small phytoplankton in marine systems. Tintinnids are distinguished from other members of this group because they create an exoskeleton or test made of foreign particles that have been cemented together.

Total nitrogen (TN) - the concentration of both inorganic and organic compounds in the water column that contain nitrogen measured in mg/L. Nitrogen is a required nutrient for protein synthesis. Inorganic forms of nitrogen are directly available for uptake by phytoplankton while organic compounds must first be decomposed by bacteria prior to being available for use for other organisms. High levels of total nitrogen are considered to be detrimental to living resources either as a source of nutrients for excessive phytoplankton growth or as a source of excessive bacterial decomposition that can increase the incidence and extent of anoxic or hypoxic events.

Total phosphorus (TP) - the concentration of both inorganic and organic compounds in the water column that contain phosphorus measured in mg/L. Phosphorus is a required nutrient for cellular metabolism and for the production of cell membranes. Inorganic forms of phosphorus are directly available for uptake by phytoplankton while organic compounds must first be decomposed by bacteria prior to being available for use for other organisms. High levels of total nitrogen are considered to be detrimental to living resources either as a source of nutrients for excessive phytoplankton growth or as a source of excessive bacterial decomposition that can increase the incidence and extent of anoxic or hypoxic events.

Total suspended solids (TSS) - the concentration of suspended particles in the water column, measured in mg/L. The composition of total suspended solids includes both inorganic (fixed) and organic (volatile) compounds. The fixed suspended solids component is comprised of sediment particles while the volatile suspended solids component is comprised of detrital particles and planktonic organisms. The concentration of total suspended solids directly affects water clarity that in turn affects the development and growth of submerged aquatic vegetation.

Zoea - last planktonic larval stage of crustaceans such as crabs and shrimp. Numbers of crab zoea may reflect the recruitment success of adult crabs.

Zooplankton - the animal component of the plankton that typically includes copepods, cladocerans, jellyfish and many other forms.